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ABSTRACT

This document reports on a study conducted by the National Science Foundation (NSF) that examines the Advanced Technological Education (ATE) program. ATE aims to promote systemic reform of the nation's science, technology, engineering, and mathematics (STEM) education. The study analyzed the influence of the ATE program on the nature of STEM programs in community colleges, the partnerships they formed, and the characteristics of the colleges in which they are located. Six ATE projects and four national centers were examined between October 2000 and January 2002. Information was gathered through site visits and ATE project and center websites. The study aimed to answer questions regarding how the ATE centers influence STEM pedagogy, how inquiry-based teaching infuses underlying academic knowledge into the training of technicians, what role ATE programs play in developing and improving articulation between community colleges and four-year institutions, and a number of other questions. A central goal of the study was to analyze the ATE projects and centers with respect to the institutionalization and sustainability of ATE-initiated or funded activities once funding ceases. The study found that output strategies have been more prevalent in the programs than process-oriented approaches, in spite of the fact that process-oriented strategies are more sustainable. The NSF would like to see the innovations and reforms that it funds institutionalized and sustained once ATE funding ends. (Contains 36 references.) (NB)

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INSTITUTIONALIZATION AND SUSTAINABILITY OF THE NATIONAL SCIENCE FOUNDATION'S ADVANCED TECHNOLOGICAL EDUCATION PROGRAM

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EXECUTIVE SUMMARY

In response to the 1992 Scientific and Advanced Technology Act (SATA), the National Science Foundation (NSF) initiated the Advanced Technological Education (ATE) program to promote systemic reform of the nation's science, technology, engineering, and mathematics (STEM) education. It had the goals of expanding the pool of skilled technicians in advanced technology fields and increasing the quality of technical and scientific education, in order to increase the nation's productivity and competitiveness in these areas. The Act gave community colleges the central role for the implementation of the ATE program.

The study reported here analyzed the influence of the ATE program on the nature of STEM programs in community colleges, the partnerships that they formed, and the characteristics of the colleges in which they are located. It also examined the steps taken to promote the sustainability of the ATE reforms and innovations once the NSF funding has ceased or been significantly reduced. The research for this report was funded by the NSF.

The Advanced Technological Education Program

The Advanced Technological Education Program Act seeks to improve science and technical education at associate degree-granting colleges and secondary schools, encourage college outreach to high schools for recruitment purposes, and improve the educational opportunities of postsecondary students by creating comprehensive articulation agreements and planning between two-year and four-year institutions.

In accordance with this mission, the Act specifically endorses the following activities: the development and use of exemplary educational materials, courses, and curricula, and their introduction in new educational settings; the preparation and professional development of college faculty and secondary school teachers; internships and field experiences for students, faculty, and teachers; and the broad dissemination of exemplary educational materials and pedagogical strategies that have been developed through previously-funded ATE awards. These activities are implemented through two major formats. *ATE centers* are intended to collaborate with multiple institutions, including two-year and four-year colleges, universities, secondary schools, and industries within a region or across the nation; to provide models and leadership for other projects; and to act as clearinghouses for instructional methods and materials. *ATE projects*, more limited in scope than centers, focus on one or more activities, including these: curriculum and educational materials development, program improvement, professional development for educators, technical experiences, and laboratory development.

Since the first ATE grant was made in 1994, more than 450 ATE grants have been awarded to community colleges. Approximately $304.2 million was appropriated by the end of fiscal year of 2003. At the beginning of 2003, there were 21 Centers of Excellence and other large-scale dissemination projects, and approximately 200 smaller projects receiving ATE funding from the NSF.

Description of the Study

Study Sample and Methodology

Six ATE projects and four national centers were closely examined between October 2000 and January 2002. Information was collected by three researchers through

two- or three-day visits to each of the sites, as well as through information available on the ATE website and the websites of the individual projects and centers. We were assisted by an advisory board consisting of a community college president, a former Principal Investigator (PI) of an ATE center (not one of those included in our sample), and an expert on technological innovation and diffusion.

Research Questions

To help determine the viability of the ATE's long-term objectives, our study attempted to answer the following questions:

- How does the work carried out by the ATE centers and projects influence the pedagogy of STEM education of the programs directly funded by the ATE and of the institutions in which they are located?
- What are the experiences of ATE PIs in promoting an inquiry-based approach to teaching that infuses underlying academic knowledge, including science and mathematics, into the training of technicians?
- What are the direct and indirect ways that ATE activities promote the involvement of a wide range of the school's departments and faculty in STEM education?
- What is the role played by ATE centers and projects in developing and improving articulation between community colleges and four-year institutions?
- What are the experiences of ATE centers and projects with regard to developing relationships with business and industry, and do these relationships have broader effects on the relationship between the college and local businesses?

- What strategies are used by the ATE centers and projects to promote the sustainability of the ATE activities after the end of, or significant reduction in, NSF funding?

To answer these questions, we examined the major activities of the ATE projects and centers in these five broad areas:

(1) The development, implementation, and dissemination of curriculum and other instructional materials;

(2) Professional development of college faculty and secondary school teachers;

(3) Efforts to strengthen science, technology, engineering, and mathematics (STEM) education in high schools and to increase the numbers of high school students into STEM postsecondary programs;

(4) Articulation and transfer; and

(5) Partnerships with industry.

Conceptual Framework

To study how the centers and projects relate to the larger issues that govern the ATE program, we developed a conceptual framework consisting of several facets for considering the sites' perspectives and activities.

We were specifically concerned with the ability of the centers and projects to meet the ATE's goal of having a significant and permanent influence on their host colleges and on the system of STEM education in general. Thus, we considered the *institutionalization* of the sites: the extent to which their activities are becoming incorporated into the normal, ongoing activities of the college. We also considered

sustainability: the state in which the major activities of the ATE program continue after the grant expires. We analyzed and assessed measures taken by the ATE sample sites to promote the long-term influence of their activities and innovations to determine their sustainability—keeping in mind that some activities are designed to solve specific problems and thus could logically be discontinued when they accomplish their goal.

Finally, we considered the sites in light of two broad classes of problems that the NSF is trying to solve through its ATE program. The first problem is the absence of an adequate curriculum and a shortage of professors and students for technical programs in community colleges; its solutions would involve increasing the available curricula, professors, and students. We refer to these activities as *output-oriented*. The second problem concerns the characteristics of the environment that give rise to these shortages; its solutions involve changing that environment. Since this perspective emphasizes the institutional processes of curriculum and professional development, we call them *process-oriented* solutions.

Study Findings

Accomplishments of the ATE Sites

The ATE projects and centers have been successful in developing activities with characteristics that match many of the objectives of the original ATE initiative.

The ATE projects and centers have emphasized the development of new curricula for scientific and technical fields. In most cases, these curricula reflect an emphasis on a strong academic content in occupational education, which is one of the central tenets of the ATE program. Some of the sites we studied were also experimenting with modularized curricular strategies that potentially can provide more learning benchmarks

and flexibility to a student's educational program. ATE grantees have also created professional development opportunities to help faculty learn to use the new curricula. In addition, they have successfully engaged technical faculty in the development of the ATE curricula and, in many cases, technical faculty have used the ATE materials in their classes. The participation of these faculty, combined with the strengthened curricula, is evidence that the ATE is making progress in reforming technical education in community colleges.

Some of the sample sites have made general progress in interdepartmental collaboration, working to break down traditional barriers. Two conditions appeared to facilitate these developments. First, colleges seeking to increase collaboration developed both formal and informal structures that brought together faculty and administrators from diverse parts of the college. Second, the goal of these ATE sites was to enhance reform strategies that were already in place; college faculty and particularly administrators saw the NSF funding as a tool to help bring about reforms that they were already pursing.

Industry has provided ATE sites with strong support, including resources, equipment, advice, internships, and jobs for graduates. Many ATE grantees have worked closely with employers in the creation and design of curriculum, skill standards, and professional development in order to gain access to knowledge about the latest technological developments and skill requirements in the industries. While individual firms are often focused on their specific skill needs, industry associations usually have a broader conception of the nature of necessary skills, and, thus, are more likely to be supportive of efforts to strengthen the academic content of technical education or to integrate academic and technical instruction.

Finally, the ATE initiative has promoted significant inter-institutional collaboration. ATE PIs have overseen the development of relationships among the community colleges, high schools, and four-year colleges. Work with high schools among the sites that we studied has been particularly impressive, and changes in the high school curriculum have been particularly noteworthy. Grantees also made use of faculty from four-year colleges for curriculum and professional development. These relationships, if they are sustained, can strengthen the environment in which STEM education takes place.

Conceptual Framework and Study Findings

The work of ATE centers and projects we studied has provided valuable insights about how the conceptual framework we developed has been operationalized, and what changes are needed to increase the ATE's positive impact on their host colleges, partners, and technical education students.

Considering *sustainability*, we sought to determine whether permanence is desirable or necessary at the sample sites. Certainly some ATE projects may not have been successful, and therefore should not continue. This is a normal and expected result of a broad program designed to encourage risk taking and innovation. Also, some ATE activities may be aimed at solving one-time problems and, once they are solved, activities can cease. For example, a new technology arises for which there is no curriculum; once that material is prepared and disseminated additional resources and effort may not be necessary. In cases where the ATE-funded activities should be continued, we suggest two alternatives. In one, outside funds and extra effort continue to be necessary even after

ATE funding has ceased. In the second, the ATE initiative leads to internal programmatic or organizational changes within the colleges—*institutionalization* of the perspective or activities—so that the ATE "innovation" in effect becomes a standard procedure. In that case, new outside funding would be less necessary.

Application of another concept—determining whether a center or site has an *output-oriented* and *process-oriented* perspective—enabled analysis of some of the strategic alternatives employed by the sites, and also permitted further investigation of the institutionalization and sustainability of their activities. We found that, so far, ATE projects and centers have put most emphasis on output-oriented strategies such as the development and dissemination of new curricula and efforts to recruit high school students. Some of the projects and centers have also initiated elements of process-oriented strategies, for example, involving academic faculty and creating interdepartmental structures that can help break down the traditional academic/occupational divide; and developing partnerships with outside businesses and educational institutions can potentially change the environment in which curricula are developed, disseminated, and taught.

Some of the most interesting process-oriented strategies can be seen at the high schools where some of the colleges in our sample sites worked. In most of the colleges ATE activities concentrated on occupational and technical courses. However, at some of the high schools ATE activities were focused on the core academic science courses as well as on the occupational or technical courses. But despite these examples, process-oriented strategies were less developed than output-oriented approaches. For the most part, the ATE was implemented within the traditional structure of the community college,

not challenging the tension between technical and academic organization and instruction. While technical faculty were active both as users and developers of ATE material, academic faculty were primarily involved with curriculum development, and even that involvement was often not extensive. Except in the high schools, the ATE projects and centers had not influenced the content or pedagogy of academic courses. Thus, the ATE has promoted a reform of technical courses rather than a more broad-based integration of academic and technical instruction throughout the college. We also found that transfer was not a priority in the ATE sites. While ATE technical curricula had stronger academic content, in many cases, those courses were still not transferable. Moreover, we noted a trend towards short-term or non-credit courses, and these types of courses are usually not transferable either.

Over the long run, process-oriented approaches are more likely to institutionalize ATE reforms, so those centers and projects that have concentrated primarily on output-oriented strategies may have a more difficult time sustaining their gains. Sustainability is certainly possible without institutionalization, but in most cases it will require additional outside funding to replace the NSF resources when the ATE grants run out. Sites may secure funding from industry, foundations and other sources of soft money, and the colleges that host the centers and projects.

It is not surprising that output-oriented strategies have been more common. First, the internal structure of colleges, particularly the division between academic and technical instruction, is long-standing and well established. Moreover, there is no consensus within the faculty, particularly academic faculty, at community colleges that this division should change. It is easier, therefore, for ATE staff at a college to avoid this

conflict and focus their attention on changing the content of technical courses or even short-term or non-credit courses, where they are likely to meet much less resistance.

Even the enthusiastic involvement of industry may limit the depth of reform. While industry associations tend to support broader educational innovations, the short-term firm-specific interests of particular employers may not always be consistent with the broader educational goals of the ATE. We found both types of influences among the partnerships developed by the centers and projects that we studied.

In addition to these factors, the structure of the ATE program, the system of RFPs, and the granting of soft money to colleges also tend to create incentives for output-oriented rather than process-oriented approaches. Soft money operations within educational institutions tend to operate at the margins of those institutions, and are therefore relatively weak tools for bringing about internal substantive or organizational changes.

This does not mean that the ATE centers and projects cannot bring about process-oriented reforms. Indeed, in our sample, we have seen important progress. Funding from soft money does mean, though, that the NSF and its contractors face significant barriers to achieving broader, structural changes. It is not surprising that during the early years of the program, ATE PIs did not start with the most intractable problems. There was plenty of important progress to be made without challenging well-established organizational structures and cultures. But now, with a ten-year track record of widespread reform of STEM education, the NSF may have the opportunity to shift the emphasis. Indeed, this appears to be what is happening. In the last few years, through the design of its RFPs, the NSF has sought to strengthen reforms that would be considered process-oriented. In

particular, it has strengthened provisions encouraging more attention to transfer and articulation and program reform (as opposed to materials development). The RFP-specified focus of the regional centers, the latest type of center provided for by the ATE program, explicitly calls for efforts to change programs and systems. Thus, we would expect to find more widespread attempts to pursue process-oriented strategies among more recently established centers and projects.

Recommendations

Our first recommendation is that in planning for ATE projects and centers, *the applicants and the NSF staff need to be specific about the problem that they are trying to solve*, or more specifically, about the circumstances that stand in the way of solutions and improvements. The education system creates and disseminates instructional material, organizes professional development, and develops partnerships with business and other educational institutions. Why are these normal organizational processes not adequate without additional ATE resources? Some possible problems include the following: (a) insufficient appropriate instructional materials; (b) a lack of adequate academic content in the existing materials; (c) no instructors who can develop appropriate instructional materials; (d) no instructors to teach existing appropriate instructional materials; (e) no distribution channel for these instructional materials; (f) a shortfall in the number of students who come to technical programs in the college; (g) too few technology/occupational students who go on to advanced STEM programs; (h) general education programs that do not connect theory to application; and (i) the organization or cultures of colleges thwarting the introduction of innovative material or pedagogies.

Different causes imply different solutions, and the nature of those solutions will in turn influence the most appropriate level and nature of institutionalization and sustainability.

The first recommendation suggests a second one: *the need for design incentives to investigate and promote broader programmatic and organizational innovation*. The NSF staff, ATE applicants, and operators of current ATE projects and centers need to be aware that the underlying characteristics of the initiative tend to promote a particular type of solution (i.e., an output-oriented approach). In many cases, this approach may be the most appropriate solution, but special provisions will need to be made in situations where the NSF and college staff judge that a different type of approach is needed. Though a trend towards more flexibility is already evident in the evolution of the ATE RFPs, the ATE operators at the college level also need to make special and conscious efforts to achieve process-oriented changes when necessary.

In the projects and centers that we studied, there are interesting efforts by ATE staff members to engage more intensively with their host colleges. In some cases, these efforts have sought to bring about deeper change within the college, particularly through breaking down the divisions between academic and technical education. Gaining support from four-year colleges can also help to create an environment more conducive to cooperation between academic and technical faculty in community colleges. Further, the involvement of industry organizations is particularly important, since they tend to have a broader view of the needs of industry than individual firms, but the interest of industry organizations is difficult to sustain, and the possibility exists of potential conflicts between the broad educational goals of the ATE and the firm-specific interests of individual employers.

The NSF ATE grantees, and their partners in four-year colleges and industry, need to engage in a broad discussion about articulation and transfer to baccalaureate-granting institutions. The optimal solution would be a two-year degree that would provide the immediate skills sought by employers and also serve as the first two years of a bachelor's degree. This education model requires a willingness of educators to rethink the nature of prerequisites for upper division courses and of employers to take a broad view of the types of skills that they are seeking. The ongoing discussion of modern innovative workplaces, sometimes referred to as high-performance work organizations, suggests that the tension between immediate work preparation and preparation for additional education should be diminishing.

Third, we believe that there is a need for several types of *new research explorations*. We have argued that the division between technical and academic instruction in colleges is an important barrier to more thorough reform of technical education but resistance from faculty, staff, and college constituencies persists. Similarly, improving articulation and transfer is made more difficult by disagreements about the amount of academic or general education courses needed for terminal occupational degrees as opposed to transfer-oriented programs. This dissension suggests a broad research agenda to explore the best ways to combine academic and technical instruction, both to meet the needs of the job market and to prepare students for subsequent education. Such a research agenda should also be of interest to other programs within the NSF.

This study also clearly suggests the need for a research project tracking the experience with ATE activities after the end of, or significant reduction in, NSF funding.

Studying a sample of post-funding projects and centers could provide useful findings, such as identifying which activities, if any, continue; exploring the nature of the relationship between NSF-funded projects and centers and the colleges (institutionalization); and identifying alternative funding sources attained.

The NSF and ATE grantees need to continue to work towards a better understanding and measurement of the outcomes of the project. Our project has looked at intermediate outcomes: institutionalization and sustainability. They are intermediate in the sense that they are means to an end—more and better educated STEM technicians—rather than the end itself. While our analysis can tell us a great deal about the program process and the potential mechanisms through which it might work, in the end we will need more evidence of the eventual program effects. This type of information will allow us to gain more understanding about institutionalization and sustainability. For example, we may find that different types of institutionalization lead to different types or levels of outcomes. Studying outcomes in a program that is as diverse and decentralized as the ATE is extremely complex. The characteristics of the program make a straightforward experimental design difficult, especially at this early stage of the program's development. Nevertheless, considerable progress can be made through a better and more comprehensive understanding of the changes that the ATE initiative has brought about in the country's system of STEM education. Most projects and centers have their own evaluators, and one step might be to work towards more standardization of their efforts and to promote more communication among them.

So far the National Science Foundation's Advanced Technological Education program has a solid record of accomplishment, particularly in the influence that it has had

on curriculum and professional development, and on bringing together community colleges, universities, high schools, businesses, commercial publishers, and other groups in a unique initiative to improve the education of STEM technicians at a time of rapid and profound change in the technologies with which those technicians must work. Our report suggests that the ATE program now has a solid base on which to promote a stronger focus on broader organizational and cultural change. The NSF, in its management of this initiative, is already moving in that direction. We suggest that this shift can be further strengthened by a more explicit understanding of the barriers that the program is trying to overcome and by carefully tracking the experience with, and effects of, overcoming those barriers.

CHAPTER 1

RESEARCH BACKGROUND AND CONCEPTUAL FRAMEWORK

In response to the 1992 Scientific and Advanced Technology Act (SATA), the National Science Foundation (NSF) initiated the Advanced Technological Education (ATE) program to promote systemic reform of the nation's science, technology, engineering, and mathematics (STEM) education. Specifically, this initiative is designed to expand the pool of skilled technicians in advanced technology fields, and to raise the quality of technical and scientific education, with the objective of increasing the nation's productivity and competitiveness in these areas (NSF, 1999; SATA, 1992). The Act gave community colleges the central role for the implementation of ATE. This mandate represented a significant federal commitment to this large education sector, and it was the first major NSF education initiative directed explicitly at community colleges. It also signaled Congress' conviction that mid-level technical occupations are growing in importance to the economic strength of the country.

The purpose of this study was to analyze the influence that the ATE program has had on the nature of STEM programs in community colleges, the partnerships that they formed, and the characteristics of the colleges in which they are located. It also examined the steps taken to promote the sustainability of the ATE reforms and innovations once the NSF funding has ceased or been significantly reduced. The research was funded by the NSF.

The Advanced Technological Education Program

In order to meet its broad and ambitious goals, the Act articulates the following objectives (SATA, 1992):

(1) To improve science and technical education at associate degree-granting colleges;

(2) To improve secondary school and postsecondary curricula in mathematics and science;

(3) To improve the educational opportunities of postsecondary students by creating comprehensive articulation agreements and planning between two-year and four-year institutions; and

(4) To promote outreach to secondary schools to improve mathematics and science instruction.

The ATE program operates through a system of RFPs (Request for Proposals). The ATE approach to bringing about change in the community colleges could be called a *RFP innovation reform* model. Every year the NSF invites groups, each of which must include a community college, to submit proposals that adhere to a particular set of specifications. The ATE program encourages the following activities (NSF, 2000; NSF 2001; NSF, 2002):

- The adaptation of exemplary educational materials, courses, and curricula to new educational settings;
- The design and implementation of new educational materials, courses, laboratories, and curricula;

- The preparation and professional development of college faculty and secondary school teachers;
- Internships and field experiences for students, faculty, and teachers; and
- The broad dissemination of exemplary educational materials and pedagogical strategies that have been developed through previously-funded ATE awards.

These activities are implemented through two major formats: ATE centers and ATE projects. They usually focus on particular occupations or substantive technology areas such as computer and information, telecommunications, manufacturing, engineering, or environmental, biological, agricultural, marine, and chemical technologies. Centers are intended to have a broad impact on education related to particular technologies or industries through collaborations with multiple institutions, including two-year and four-year colleges, universities, secondary schools, and industries within a region or across the nation. They are expected to provide models and leadership for other projects, and to act as clearinghouses for instructional methods and materials. There are three types of centers: National Centers of Excellence, Regional Centers, and Resource Centers.[1] Each National Center receives up to $5 million spread over four years, with the possibility of renewal for an additional three years. Regional Centers are designed for projects on manufacturing or information technology education, and receive

[1] National Centers of Excellence are designed to have a national impact, and engage in the full range of activities associated with ATE projects (including program improvement, professional development, curriculum and educational materials development, technical experience, laboratory development, research, recruiting, retention, and articulation programs) with a broad group of institutions including high school, two-year and four-year institutions, business and industry, government, and commercial publishers. Regional Centers for Manufacturing or Information Technology Education are expected to reform academic programs and departments as well as technical education in the areas of IT and manufacturing technology in order to meet industry's needs within a particular geographic region. Resource Centers generally consist of ATE national or regional centers or exemplary ATE projects that have completed their original grants. For the improvement of educational programs in a particular filed of technology, these centers provide instructional materials and design, curricula, and other supports developed through the previous fund.

up to $3 million spread over four years. Resource Centers receive up to $1.5 million spread over four years. While centers are comprehensive in scope, ATE projects focus more narrowly on one or more activities, including: (a) curriculum and educational materials development; (b) program improvement; (c) professional development for educators; (d) technical experiences; and (e) laboratory development. The average project grant has been about $400,000. For the year 2002, the grants for projects ranged from $25,000 to $300,000 per year and last for up to three years.

In addition to the center and project grants, since the year 2002, the ATE program has set up a new grant track that supports the creation and implementation of articulation agreements. For the articulation partnership program, the NSF has allocated from $50,000 to $100,000 per year for a duration of three years. This incentive aims to facilitate the transitions of students from STEM associate degree programs to related bachelor's degree programs. Also, the articulation partnership is expected to strengthen the technological knowledge and skills of K-12 teachers in the fields of science and mathematics at secondary schools.

Since the first ATE grant was made in 1994, more than 450 ATE grants have been awarded to community colleges. Approximately $304.2 million was appropriated by the end of fiscal year 2003. At the beginning of 2003, there were 21 Centers of Excellence and other large-scale dissemination projects, and approximately 200 smaller projects receiving ATE funding from the NSF. In terms of expenditures, ATE Centers have accounted for 28.2% of funds allocation ($85.7 million of $304.2 million); ATE Projects for 58.4% ($177.8 million); ATE Articulation Partnerships for 1.8% ($5.4 million); planning grants for 0.8% ($2.3 million); co-funding, supplements, and special projects for

5.4% ($16.4 million); and management, reports, and other leadership activities for 5.5% ($16.6 million) (G.L. Salinger, personal communication, August 8, 2003).

In addition to funding the centers and projects, the NSF makes an effort to help the grantees strengthen their ability to deliver the appropriate services. It has done this both through funding an evaluation by the Western Michigan University Evaluation Center (Lawrenz & Keiser, 2002), and an annual conference of principal investigators (PIs), which is perhaps the most important forum for this type of organizational and professional development. The conference, which is organized in conjunction with the American Association of Community Colleges (AACC), offers a variety of workshops at which principal investigators and their associates can share information, discuss the lessons they have learned, and report on their progress. Centers and projects are also offered the opportunity to display the materials they have developed and to describe their activities.

The goals of the ATE program are not only to increase the number of STEM technicians, but also to improve the quality of education that students in these fields receive. What types of changes are the NSF trying to achieve through the program? During the last 15 years, scientists, business people, and educators have engaged in an extensive discussion of STEM education and have reached a variety of conclusions about how it needs to be improved. Many of these conclusions were summarized in *Shaping the Future: New Expectations in Undergraduate Education in Science, Mathematics, Engineering, and Technology*, the 1996 report by the Advisory Committee to the NSF Directorate for Education and Human Resources. This report concluded that STEM education had to be improved and made more accessible to undergraduate students, and

that workers who held technical jobs typically filled by individuals with a community college education needed a stronger base of scientific and mathematical knowledge. These conclusions were consistent with the recommendations of other analysts who argued that in the increasingly complex workplace, industries want workers who can solve problems, work in less well-defined circumstances, and take initiative and responsibility (Bailey, 1995; Barley & Orr, 1997; Murnane & Levy, 1996). Reformers suggested that more emphasis must be put on interdisciplinary curricula and the integration of academic and occupational or technical[2] instruction, and that pedagogy needs to be based on more active learning rather than didactic lecture-based approaches. An applied approach to teaching and learning might help strengthen academic skills by providing a context and motivation for learning those skills (Bailey, 1997; Brown, 1998).[3] This perspective gives a special pedagogic role to occupational or technical education, beyond teaching the specific occupational skills, since such education is much more likely to make use of applied or hands-on teaching. The changing demands of the workplace do suggest a need to strengthen academic instruction in occupational

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[2] In this report, we use the words "technical" and "occupational" interchangeably. In the field, usage is shifting from "occupational" to "technical" primarily because of the conviction that the term "occupational" has an anachronistic connotation suggesting narrow vocational training that neglects academic skills and focuses instead on practical tasks of an occupation. The disadvantage of the term "technical" is that it is not well defined. But recognizing that one of the ATE's central goals is to strengthen the academic content of occupational education, for the most part, we use the term "technical" in this report.

[3] The basic rationale is that students will learn better when courses are taught in a real-world context, by connecting the classroom to the workplace, and abstract concepts or knowledge to real problems (Keif & Stewart, 1996; Stasz 1997). Several early psychologists, such as Thorndike (1931) and Hull (1943), had already discussed the importance of associating different elements in learning. The recent cognitive theorists have added a constructivist dimension, contending that learning is a process of knowledge construction rather than knowledge memorization, absorption, or storage (Beane, 1998; Biggs, Hinton, & Duncan, 1996). This concept of the constructivist pedagogy reflects the philosophy on which academic and vocational integration is based: instruction has to forge connections between knowledge development and its application in the workplace (Brown, 1998).

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programs, but occupational skills and pedagogy often used in modern technical education also have a role to play in strengthening academic learning as well.

By anchoring the program in the community colleges, Congress was signaling its commitment to increasing the quality and quantity of associate degree-level scientific and technical personnel. This is an important emphasis since many parents, students, educators, and policy makers believe that the baccalaureate degree is the gold standard of higher education. By emphasizing the community colleges, Congress endorsed the important role that associate-level graduates can play in strengthening the technical and scientific base of the economy. And, as we shall show, during the ATE's first few years, PIs and staff have indeed focused on preparing these workers.

At the same time, since the late 1990s, the NSF has also encouraged grantees to strengthen the opportunities for community college students to transfer and pursue bachelor's degrees. Thus the ATE program is designed to prepare students for work based on an associate degree but also to be prepared for additional education if they choose to pursue it. A new program track focused on articulation is the best example of this.

In addition, through the ATE, the NSF has put great emphasis on the development of partnerships between community colleges and business and industry. The original act that set up the ATE called for "partnerships between the private sector and associate-degree granting colleges" (SATA, 1992). The 2002 ATE RFP issued by the NSF stated that ATE centers required "strong collaboration of educational institutions with business, industry, and government, especially with regard to identifying needed technical skills, planning curricula, and establishing internships for students and faculty."

Institutionalization and Sustainability

Part of our analysis is therefore focused on assessing the extent to which ATE-inspired programs have adopted more integrated pedagogies with stronger emphases on academic skills, developed stronger provisions for articulation and transfer, and developed collaborations with business and industry. However, now that the ATE program is well established, as the NSF looks to the future, it is appropriate to consider the broader and longer-term effects of the ATE initiative. It is important to question whether the ATE program goes beyond influencing the particular programs that it funds, has a significant influence on the host colleges and eventually on the system of STEM education, and whether the ATE-promoted innovations will outlast the NSF funding. Therefore, this report also examines these broader issues. We studied what we call "institutionalization": the state in which the ATE activities become incorporated into the normal, ongoing activities of the college. We also analyzed and assessed measures taken by ATE program grantees to promote the long-term influence of their activities and innovations. We refer to this as "sustainability": the state in which the major activities of the ATE program continue after the grant expires.

Sustainability is particularly important because of the tendency for grant-funded reforms to fade away when the funds run out, a concern voiced in the aforementioned 1996 report *Shaping the Future: New Expectations in Undergraduate Education in Science, Mathematics, Engineering, and Technology*, by the Advisory Committee to the NSF Directorate for Education and Human Resources. This is an endemic problem in educational reform. Organizational theorists have established that the technical activities

of educational organizations, those directly related to educating students, are typically loosely coupled with the more public activities of administrators and leaders (Brint & Karabel, 1991; Meyer & Rowan, 1977; Meyer, Scott, & Deal, 1981). This practice explains to some extent why funded projects in educational institutions are often poorly integrated into the overall operations of those institutions. Since such funding is often considered temporary, grant recipients encounter institutional reluctance to incorporate reforms into core activities. For example, in their study of the role of federally funded programs in K-12 educational reform, Meyer, Scott, & Strang (1987) found that although these programs were designed to influence the behavior of teachers, they had greater impact on the activities of district and state administrators. Likewise, DiMaggio's (1983) study of the impact of funding from the National Endowment for the Arts found that the funding had greater influence on state arts councils than on the arts organizations themselves. These findings suggest that even if administrators support the ATE activities, they may have difficulty in using them to reform the ways that faculty teach and students learn across the college. It may be easier to implement a special program that is either independent or at the margins rather than in the core of the college.

Institutionalization is related to sustainability, but it is not the same thing. ATE activities could be sustained even if they are not institutionalized, through alternative soft money funding or product sales. But if the curriculum, pedagogic reforms, and the enhanced partnerships encouraged by the ATE activities are incorporated into the regular operation of the college and its course and curriculum development procedures, then it is likely that its influence will be sustained. Thus an institutionalized reform is likely to last. It is possible that even institutionalized reforms can eventually be reversed. Established

procedures can be amended or circumvented, but institutionalization will go a long way to promoting sustainability.

Institutionalization and sustainability cannot be understood and analyzed in the abstract. We can make sense of them only in the context of an understanding of the problem that the NSF is trying to solve or the opportunities that the agency is trying to exploit through its ATE program. To be sure, the ultimate goal of the program is to increase the number and quality of STEM technicians and scientists. But why is a special federal-level initiative needed in the first place? After all, the educational system, commercial publishers, and other existing institutions create curricula and prepare teachers and professors to teach them without the assistance of the federal government. Industry has an interest in seeing that educational institutions are appropriately preparing their future workers, colleges have an interest in educating their students to work in growing fields, and students have an interest in preparing for those fields. Why is this complex set of interests not producing the optimal number of appropriately prepared technical and scientific workers? The answer to these questions will help to determine the nature of the most appropriate strategy and it will have a profound influence on the nature and desirability of institutionalization and sustainability.

We distinguish between two broad classes of problems that the NSF is trying to solve through its ATE program. The first focuses on the absence of an adequate curriculum and a shortage of professors and students for technical programs in community colleges. The solutions implied by this perspective seek directly to increase the available curricula, professors, and students. We refer to these as *output-oriented* explanations. The second focuses more on the characteristics of the environment that give

rise to these shortages, and solutions focus on changing that environment. Since this perspective emphasizes the institutional processes of curriculum and professional development, we refer to these as *process-oriented* explanations. We will discuss each in more detail below.

Output-Oriented Explanations and Solutions

Why is there a shortage of appropriate curricula and faculty? One possibility is that technology is simply changing too rapidly for the country's educational system to keep up. Microelectronic and network technologies have led to an explosion of technologies and technological applications, and educational programs to prepare students to work with these technologies need almost continuous updating. This is perhaps obvious in fields like information technology (IT), semiconductors, and biotech, but these innovations also have profound effects on more "traditional" industries such as manufacturing, construction, and agriculture.

This need for constant educational innovation is complicated by three problems. First, while the burden of responding to rapid technological developments has often fallen on community colleges, these colleges have fewer resources with which to make the investments needed to keep courses up-to-date than do four-year colleges. These resource constraints are further exacerbated by difficulties that community colleges have had in finding qualified faculty, especially during the boom of the 1990s, since potential candidates may have attractive employment options in the private sector. When colleges are short of faculty, existing faculty are burdened with heavy teaching loads, often preventing them from developing new materials and courses. A second problem is that

the speed of change is complicated by the need to introduce new pedagogies and to strengthen the academic content of technical programs. Thus, professional development for faculty must be a crucial component of ATE activities. A third problem is that students are often not enthusiastic about pursuing technical jobs, especially in more traditional industries like manufacturing and construction (Dunn, 1999, Hayes & Kellar, 2002). Changing social perspectives on occupational prestige, and a growing conviction that the bachelor's degree is the real ticket to the middle class, have left many high school students and their parents unenthusiastic about technical careers that require sub-baccalaureate preparation, despite the increasing technological sophistication of these occupations.

The perceived shortage of qualified technical and scientific personnel for mid-level positions can be addressed by providing some funds that the colleges can use to stay up-to-date technologically, through curriculum, dissemination, and professional development; and to provide accurate information to high school students about the opportunities and technical sophistication of these occupations. These programs funded by the ATE initiative would therefore be aimed at directly increasing the available curriculum, faculty, and students. And indeed, as we shall see, such activities are important components of many ATE centers and projects. Since the focus of this approach is to fund programs that will increase directly the number of educated technicians, we refer to this as an *output-oriented* strategy.

Process-Oriented Explanations and Solutions

The NSF's background research and discussion associated with the development of the ATE program suggests that problems may lie deeper than the pace of technological change and the need to help faculty catch up with new approaches to teaching. It may be that innovations in teaching and program design can take root only through changes in the organization and culture of educational institutions, the nature of the interactions within those institutions, and the relationships among educational institutions and among colleges, businesses, and other community stakeholders.

Studies on the evolution of innovations in technical education have identified various barriers to disseminating the new pedagogical approaches to both secondary and postsecondary schools. In early observations on community colleges, Grubb and Stasz (1993) and Boesel (1994) reported that community colleges have made little progress in implementing academic and vocational integration, partly because the idea was not disseminated widely enough. In a later study, Grubb (1999) found significant institutional barriers to the diffusion of innovative pedagogy. Critics argue that faculty and students in programs offering terminal vocational education have little or no interaction with faculty in the traditional academic areas or with students preparing to transfer to a four-year institution. Academic faculty members often look down on professors in technical areas. Partly because of the lack of communication and interaction between technical and academic faculty, participation in a vocational program often does not prepare students for transfer to a four-year program, thereby limiting their educational opportunities. Perin (1998) also found that despite enthusiasm for academic-occupational integration, few

programs have carried out a comprehensive implementation of the reform, and actual examples are few. She points out that obstacles to integration abound in terms of the cost in time, effort, and expenditures needed for professional development and instructional planning. Other researchers have found persistent concern among faculty in both academic and technical programs about the use of integrated curricula in their classes, and this concern often translates into resistance to the introduction of such instruction (Dennison, 1993; Green, 1993).

The Advisory Committee to the NSF's Division of Undergraduate Education reached similar conclusions, pointing out that implementation of many of the needed reforms of occupational education was sporadic and weak. According to the Committee, a variety of institutional barriers stood in their way (Advisory Committee, 1996). The authors argued that colleges had already introduced many reforms and that examples of most of the innovations called for in the report could already be found. But the Committee observed "the improvements achieved [in STEM education] have not been widely implemented and are not sustainable without significant change in the culture, policies, and practices of higher education" (p. 51). The Advisory Committee made several recommendations regarding how institutions can support improvement in STEM education: (a) that every institution ensure that its mission, personnel, planning, and budgeting decisions support enhanced undergraduate learning in STEM; (b) that institutions make funds available for the development, maintenance, and operation of equipment and facilities for STEM education; and (c) that colleges seek ways to reduce organizational rigidities by fostering cooperative efforts and interdepartmental work. This perspective suggests that increasing the quantity and quality of STEM personnel requires

organizational and cultural changes in the education system and innovations in the process of curriculum development. Thus, developing curricula without changing the underlying environment may not be effective or may be effective only in the short term.

If institutional change is needed, then, as a grant-funded program, the ATE faces a conundrum. It is designed to implement a set of educational reforms that is often blocked by institutional barriers, and the nature of soft money projects encourages a project organization in which the funded activities are set up with at least some independence from the core institutional features of the colleges. Thus, success of the programs requires institutional change, yet the nature of the funding tends to give ATE projects and centers little leverage over those institutional features.

Description of the Study

Clearly, the ATE's long-term objectives will not be met if successful programs eventually flounder as a result of a mismatch between the characteristics of those programs and the organization and culture of the colleges and the system in which they must operate. Our project is aimed at helping to understand these potential problems and to look for solutions.

Research Questions

We attempt to answer the following questions:

- How does the work carried out by the ATE centers and projects influence the pedagogy of STEM education of the programs directly funded by the ATE and of the institutions in which they are located?

- What are the experiences of ATE PIs in promoting an inquiry-based approach to teaching that infuses underlying academic knowledge, including science and mathematics, into the training of technicians?
- What are the direct and indirect ways in which ATE activities promote the involvement of a wide range of the school's departments and faculty in STEM education?
- What is the role played by ATE centers and projects in developing and improving articulation between community colleges and four-year institutions?
- What are the experiences of ATE centers and projects with regard to developing relationships with business and industry, and do these relationships have broader effects on the relationship between the college and local businesses?
- What strategies are used by the ATE centers and projects to promote the sustainability of the ATE activities after the end of, or significant reduction in, NSF funding?

Sample and Methodology

Our study required a detailed institutional analysis of the ATE projects and centers; therefore, rather than collect data on many projects and centers, we carried out an intensive study of a small number. We conducted visits to six projects and four centers, which were in various phases of their life-cycle, representing three stages of development: (a) initiated, the period immediately following the receipt of the grant; (b) established, two years into the grant; and (c) final, program preparation to be self-sustained. The selection of the sites was also based on factors that we have found

important in influencing the organizational structure and activities of community colleges, including region, industry, size of the community college, and level of urbanization. Finally, projects were selected in terms of the specific technology focus; we included a sample of technology programs that were relatively new to community colleges (such as simulation), as well as those that have been present for a number of years (such as construction technology).

Our site visits took place between October 2000 and January 2002, and were carried out by two or three researchers who spent between two and three days at the sites. At each site, the data were collected through semi-structured and open-ended interviews with: (a) ATE principal investigators and other ATE staff; (b) college presidents and vice presidents in administrative, academic, and vocational departments; (c) college faculty in both technological and academic departments; and (d) representatives from collaborating educational and industrial organizations. Prior to the site visits, the research team conducted telephone interviews with the PIs of the ATE centers and projects to understand the issues that contribute to, or stand in the way of, efforts to institutionalize ATE activities. Based on these interviews, protocol questions for the field research were developed to elicit information related to the history, organizational and financial structure, curriculum, and partnerships of the ATEs. We analyzed the data collected through interviews using QSR N5, a software package designed for qualitative research. Table 1.1 displays information about the ten sites that we studied.

Table 1.1: Information on Study Sample[1]

College	Type of grant	Amount of grant	Stage of grant	Industry	ATE technology	College enrollment	Urbanicity
A	Center	$5,077K for 8 years	Established to final	Information and computer	Information technology	19,000	Urban
B	Project	$340K for 2 years	Final	Pharmaceutical Manufacturing	Bio-technology	12,034	Rural
C	Project	$300K for 2 years	Established to final	Pulp, chemical, agriculture	Engineering technology	2,391	Rural
D	Project	$739K for 3 years	Initiated to established	Construction	Construction technology	65,000	Urban
E	Project	$870K for 3 years	Final	Pulp, paper, chemical	Pulp, paper, chemical technology	1,208	Very rural
F	Project	$501K for 3 years	Final	Auto manufacturing	Manufacturing technology	8,774	Suburban industrial
G	Center	$5M for five years	Final	Semiconductor manufacturing	Semiconductor manufacturing	243,000	Suburban
H	Center	$5M for six years	Final	Tele-communication	Telecom technology	7,000	Suburban
I	Project	$848K for 3 years	Near established	IT & Tele-communication	IT, telecom, and others	14,088	Suburban
J	Center	$3M for 3 years	Initial	Agriculture	Agriculture Technology	11,000	Suburban to rural

[1] Information current at time of site visit

Although we did try to select broadly representative sites, given the small size of the sample, readers should be cautious when generalizing from our conclusions. Moreover, the ATE program is not static. An examination of RFPs since the program was established suggests that the NSF focus has evolved. For example, later RFPs place more emphasis on sustainability and articulation with four-year schools. Indeed, some of the suggestions that we make in this report are already being implemented. Nevertheless, many of the issues discussed continue to be important.

Report Outline

In the next chapter, we briefly summarize the main ATE activities undertaken by the colleges in our sample. We put particular emphasis on the academic content of the curriculum developed by ATE projects and centers, and on the relationship of the ATE

curriculum to transfer and articulation. We also examine the partnerships with industry developed by the centers and projects, and examine what influence those partnerships might have on the broader educational and organizational goals of the ATE program. In the following chapter, we examine the relationship between the ATE centers and projects and the colleges in which they are housed. This examination enables a better understanding of how the ATE has influenced those colleges and the potential for institutionalization of reforms promoted by the NSF through its ATE program. Chapter 4 gathers together our insights and conclusions about sustainability. One of our main conclusions is that the optimal levels and characteristics of both institutionalization and sustainability vary according to the underlying problems that the ATE center or project is trying to solve or the opportunities that it is trying to exploit—that is, the problem or opportunity that gave rise to the need for an ATE intervention in the first place. We end with conclusions and recommendations both for the NSF and for individual colleges.

CHAPTER 2

ATE ACTIVITIES

In this section we briefly describe the main activities at the Advanced Technological Education (ATE) centers and projects in our sample. Much more extensive descriptions are available through materials developed by the overall ATE evaluation project conducted by the Western Michigan University Evaluation Center (Lawrenz & Keiser, 2002). Our purpose here is to give the reader a sense of the activities at our sample schools and to draw some conclusions about the nature of those activities.

We discuss the major activities of the ATE projects and centers in the following five broad areas:

(1) The development, implementation, and dissemination of curriculum and other instructional materials;

(2) Professional development of college faculty and secondary school teachers;

(3) Efforts to strengthen STEM education in high schools and to interest and recruit high school students into STEM programs in postsecondary programs;

(4) Articulation and transfer; and

(5) Partnerships with industry.

Curriculum and Educational Materials Development

All of the ten sites that we visited had a clear emphasis on the development and implementation of curriculum and instructional materials. Curriculum is a broad concept that defines a system for teaching the skills and knowledge needed to master a particular

occupational or substantive area. This broad system is divided up into courses, which then make use of instructional materials to teach the required skills and knowledge. These materials developed by the ATE projects and centers in our sample involve a variety of pedagogic technologies, including textbooks, laboratory experiments, manuals, software, multi-media tools, and other courseware.[4] ATE centers in particular are expected to develop high-quality materials, courses, and curricula and related professional development that are disseminated through commercial publishers, journals, conferences, workshops, on-line networks, and other means (NSF, 2002). Two projects focused particularly on the development of curricula and materials that integrate basic academics and applied technologies; other sites pursued this strategy as well. Table 2.1 summarizes the activities of curriculum and other instructional materials development

[4] The terms curriculum and instructional materials are often used interchangeably and, indeed, that was the case in many of the sites in our sample. Strictly speaking, it is possible to develop a new curriculum without developing new material by assembling and organizing existing material in a new way. In this report, we use the concepts interchangeably since, in most cases, the sites in our sample developed new material as they developed new curricula.

Table 2.1: Characteristics of Curriculum and Other Instructional Materials Development

	(1) Subject Area and Technology	(2) Major products	(3) Created New Curriculum	(4) Modularization	(5) Skill Standard
A†	Information technology	Online course-ware	X	X	X
B	Bio-technology	NC lab and curriculum	X		
C	Engineering technology	Integrated curriculum	X	X	
D	Construction technology	Integrated curriculum	X	X	
E	Pulp, paper, and chemical, technology	NC lab and curriculum	X	X	
F	Manufacturing	Simulation module	X	X	
G†	Semi-conductor manufacturing	Multi-media course-ware		X	X
H†	Tele-communication	Textbooks and CDs		X	
I	IT, Telecom, and others	Inter-college courses and programs		X	
J†	Agriculture technology	GPS/ GIS module	X	X	X

† Centers

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Columns 3 to 6 display some characteristics of curriculum development activities. Two centers and five projects created entirely new curriculum and/or other educational materials for the ATE program. We should note that modularization is a very popular approach. Modules are sometimes referred to as reusable learning objects (RLOS). Modularization, in the area of instructional design, is the development of self-contained units of curricula that can be combined in different ways.[5] Since faculty members can choose one or more units of the module on a particular subject that they teach, modularized curriculum is easily adopted and therefore disseminated relatively quickly. An example of the modularization approach was at a center that focused on semiconductor manufacturing. The center developed about 40 modules to teach semiconductor manufacturing. Each of the modules contained five to eight hours of instructional activity, and included such content as background information, learning plans, animations, PowerPoint presentations, and other educational tools. Clients included faculty and teachers in community colleges and high schools, as well as trainers in industries. They customized the combinations of the modules, sequencing them in different ways, depending on their focus in instruction, or on the needs of local industry. Faculty can then use the modules to create their own classroom instruction. The center particularly focused on adoptability, customizability, and on-line deliverability of the modules, since these elements further facilitate their use.

[5] The concept of "modularization" was originally described as a process that permits the manufacture of final products more easily and more cost effectively. This concept has spread into the area of vocational education and indicates a method of teaching that facilitates the use of learning materials in a more flexible and differentiated manner. Rapid changes in technology and skill demand by industry have required this flexibility and differentiation in teaching (Ertl, 2000; Laur-Ernst, Kunzmann, & Hoene, 2000). There have been some issues raised concerning the suitability of modularization as an approach to the development of curriculum integration, i.e., how can a student deal with complex interrelationships when the method of delivery separates the subject matter into small segments. Indeed, the popularity of modularization in community colleges comes from its usefulness in areas of customized training—an activity that promotes only specialized training and education.

Three centers created skill standards for their industries or relevant occupations in order to match skills required in industries with those produced in educational institutions, thereby establishing the content needs of curricula for these industries. In terms of the "use" of skill standards, the ATE centers and projects use such broad generic national skill standards as those developed by the Secretary's Commission on Achieving Necessary Skills, or SCANS, (1991) for the development of curriculum. But many of these centers and projects are also likely to follow narrowly defined industry- or firm-specific standards, while partially following state and national standards.

We are particularly interested in the extent to which academic skills are incorporated into the curricula and instructional materials developed with ATE resources. An examination of curricular outlines reveals the presence of basic scientific and mathematical content in the technology- or occupation-specific courses or modules. Courses can be found that include the science of oxidation and transistors, concepts in circuitry, basic principals in physics, statistical analysis, and chemical analysis. Principal investigators (PIs) from two projects particularly emphasized that they explicitly designed their curricula to integrate basic academics and applied technologies. At one project, we were told that its ATE curriculum is: for students, to explore industry's real applications of specific academic topics; and for workers, to integrate academic subjects in helping them to conceptualize what they do in the workplace. At another project that was producing learning materials for high schools, the ATE curriculum was developed to relate industry-based skill standards, SCANS, and state-mandated academic standards, thus incorporating academic, technical, and employability topics. Another high school project was focused on creating technically oriented science courses that could serve as

general high school courses for those fields. And, at one of the centers that we studied, the ATE curriculum included full courses in technical chemistry and biochemistry, although in that case, the courses were not transferable to baccalaureate-granting institutions. The Western Michigan University Evaluation Center (Lawrenz & Keiser, 2002) also concluded that ATE projects and centers that focused on program improvement reflected the "use of mathematics, science, and communications across the technical curriculum component" (p. 77). Thus, our review of these ten ATE centers and projects indicates that curriculum developers did incorporate scientific and mathematical concepts and theory into their applied courses and modules. [6]

Professional Development

Professional development at the ten sites we visited included workshops and seminars, field experiences and internships at industry sites, and also a fellowship program that sponsors community college faculty and high school teachers to study at four-year programs. Table 2.2 shows these activities by project. These teachers and faculty do not include the project PIs or Co-PIs. The table shows to what extent the projects and centers have involved faculty and teachers in the ATE program within their own colleges and in partner institutions.

All the projects and centers, except for one project, have held workshops and/or seminars for faculty, high school teachers, and/or university faculty to disseminate the use of ATE-funded curricular and other instructional materials. At Project B, in addition

[6] Our analysis only examined ATE material, we are not able to determine how this material compares to other curricula at the site. Applied science courses have been available for many subjects. What we can say is that ATE curriculum developers at our research sites put a major emphasis on including strong academic content and that content is evident in available descriptions of the material.

to the PI and Co-PI, industry partners teach the curriculum, thus no training has been provided for other college faculty members.

Those projects and centers that offered workshops/seminars where they had strong connections with a specific industry or industry organization tended to send the college faculty and/or partner high school teachers to the industry sites for field experience. Of the sites we visited, only one project offered fellowship programs. The main feature of this project was a consortium that included other community colleges and a university partner. Teachers and faculty in the consortium have been sent to the university to obtain advanced degrees.

Overall, our assessment is that ATE projects and centers were working hard on professional development. These conclusions are consistent with those of the ATE evaluators from Western Michigan University, who found that "the ATE has successfully engaged associate degree institutions and others in developing materials and programs and providing professional development services to help implement them" (Lawrenz & Keiser, 2002, p. 98). However, the WMU report also concludes that these efforts are at an early stage, and that so far the ATE grantees do not provide substantial follow-up to professional development activities and, if they do, they do not assess the impact of such follow up.

Table 2.2: Type of Professional Development

	(1) Workshop/seminar	(2) Field experience	(3) Fellowship
A†	HT, CF	HT, CF	
B			
C	HT	HT, CF	
D	HT, CF	HT, CF	
E	CF	CF	
F	CF	CF	
G†	HT, CF	HT, CF	
H†	HT, CF, UF		
I	CF		CF
J†	HT, CF, UF		

† Centers

Key
HT: high school teachers who participate in respective activities
CF: community college faculty
UF: university faculty

Work with High Schools and High School Students

Seven of the ten sites we studied had significant activities in high schools, and at three sites, work with the high schools was the most important activity at the time that we visited. At two of those three sites, the program PIs expected to work more extensively with the community colleges in the future. In one case, the ATE project was active in the

overall design of a technical high school. In another case, it was working with the high school on its general science curriculum. And in the third, the ATE project's staff members were working with local high schools on courses in a particular technology. In all three of these cases, the ATE staff emphasized their commitment to curricula that integrated technical and academic instruction. Among the ten sites studied, these sites accounted for three of the five that expressed the strongest commitment to this type of instruction. Indeed, in two of these three cases, the curriculum reform involved innovations in the basic science courses. With one exception, in all the cases studied that emphasized materials or curriculum development, ATE activities at the community college level were focused on increasing the academic content of occupational or technical courses, not changes in the core science courses. Thus, two of the projects that concentrated on high schools provided some of the best examples of a commitment to the use of more applied content in academic courses.

The ATE sites we visited were also involved with efforts to inform high school students about the opportunities in technical occupations, and these efforts involved such activities as summer camps, technology contests, field experiences, and mentoring programs. ATE staff also attempted to facilitate the transition of high school students into community college and even into four-year institutions through the development of 2+2 programs (programs that articulate the last two years of high school with two years of instruction at a community college), or 2+2+2 programs (programs that additionally articulate the third and fourth year of college with a 2+2 program). Table 2.3 shows these activities by project.

Table 2.3: Awareness and Pathway Development

Colleges	(1) Summer Camp/Contest	(2) Mentoring	(3) 2+2(+2) Building
A†	HS	HS	
B			
C	HS	HS, CC	HS, CC
D	HS	HS	HS, CC, 4-year
E			
F	HS	HS	HS, CC
G†	HS		
H†	HS		
I	HS		
J†			

† Centers

Key
HS: Indicates that respective activities take place at high schools
CC: Indicates that respective activities take place at community colleges
4-year: Indicates that respective activities take place at four-year institutions

All the centers and four of the projects had some high school-oriented program. Seven of the ten sites organized summer camps and contests, four had mentoring efforts, and three were developing 2+2 or 2+2+2 programs.

Working with high schools was an important part of the activities of most of the sites. The integration of academic and technical instruction was particularly strong in those colleges that focused primarily on work with high schools. We present more information about work with high schools in the chapter on sustainability.

Transfer and Articulation

In the last few years, the NSF has increased its emphasis on articulation and transfer in the ATE program. Articulation (between two- and four-year schools) appeared

as a separate category in the RFP for the first time in 2000. The WMU Evaluation Center study (2002), based on surveys in 1999, found that many projects and centers were working on articulation. Moreover, the importance of strengthened academic content within the ATE program is consistent with a strategy to facilitate transfer.

For the examination of transfers from community colleges to four-year programs, we investigated the characteristics of the course design, including degrees offered, coursework, and transferability of academic and technical credits. These course characteristics were examined along with the policy and practices of the host community colleges in the area of articulation management.

The issue of transferability is closely related to the instructional departments that host the ATE-related courses and facilitate articulation arrangements, and whether the ATE curricula have affected such articulation arrangements. In a situation where ATE material or courses are used in transfer-oriented programs the options for transfer will be greater for ATE students. Thus, the one ATE project in our sample that located the activities in an academic department put the most emphasis on transfer (see Table 2.4). In the case where the activities were located in workforce development divisions, transfer was much more difficult.

The centers are sometimes set up independently of any department. In most cases, these centers produced curricula or materials that were designed to be used by many colleges; here, transferability presumably depended on the characteristics of programs that used the material. In some cases, ATE material was used in customized programs designed for short-term training of incumbent workers; in these cases, the courses were not transferable. Table 2.4 depicts the characteristics of programs that run

the ATE-funded course, including the level of students for which the material and curricula are designed, the organizational location of the ATE-related course, and the degree level for which the material was designed.

Table 2.4: Course and Curriculum Characteristics for Transferability

College	Student Level			College Department Housing ATE	Degree and Certificate Offered or Planned to Be Offered
	CC students	HS students	Industry		
A†	X	X		Independent	ATS• Certificate
B	X		X	Biology	AS AAS
C		X		Business and industry	AS AAS
D		X		Technology	AAS Cert
E	X		X	Technology	AAS
F		X		Technology	AAS Certificate
G†	X	X	X	Independent	•
H†	X	X	X	Independent	AAS Certificate
I	X		X	Cont. ed & workforce development	AAS Certificate
J†	X			Technology	AAS

• These centers do not directly offer a course or degree. The district colleges that use the ATE modules offer Associate in Applied Science. In college G, students who go through the ATE modules can go directly into BAS (Bachelor in Applied Science) at a university.
† Centers

When we visited, the ATE-funded curricula were being offered for community college students at seven out of the ten colleges. Six of these programs that made use of the curricula or materials were designed to offer the Associate of Applied Science (AAS) degree, which is intended to prepare students for immediate entry to the workplace. Most of these colleges also offered certificates and specialist diplomas. Generally, the technical

or occupational courses leading to AAS degrees are not directly transferable to four-year colleges, and these six programs had transferred few students into a four-year program. At the one exception, students who studied through the ATE module could advance to the Bachelor's in Applied Science (BAS) program at a nearby state university. At this community college, an articulation agreement was set up between the college housing the ATE and the state university for AAS students to come into the BAS program.

In most of the departments hosting the ATE program, articulation is potentially possible since they have agreements with one or more local universities. The ATE PIs reported that the coursework including the new ATE curriculum could have been part of the articulation agreement, or that they were actively negotiating with community college and four-year faculty to include ATE-related courses in articulation agreements. Nonetheless, at the time of our visits, they all reported that students in technical programs using ATE curricula and materials wishing to transfer would either need to design their programs specially to take basic academic science and mathematics courses, or would need to take additional courses at the four-year college. The "applied academic courses," such as "applied chemistry" or "applied mathematics," are designed specifically for students in occupational or technology programs, and are usually not transferable. Thus, transfer is possible, but many of the technical or "applied academic" credits earned in the ATE-related program at the community college would not transfer, and students would have to make up for those credits at the four-year college. Thus, to the extent that the academic and occupational courses that technology students take are not transferable, problems are created for those students who become interested in advancing to four-year

programs during the course of their study at the two-year institution. One faculty member we interviewed stated the problem as follows:

> Some students just start with a community college. While they are in the college they discover that they can be successful and they'd really like to do something, perhaps they get a goal in life that would require them to have a four-year or bachelor's degree. Well, if they've come into the community college in a voc tech program, then much of what they have taken will not transfer to any four-year institution for a bachelor's degree because the credits are not compatible. So they already have trouble...if they really want to pursue that goal and transfer to the institution, they realize that they've lost one or two years, because very little of what they've done will work. So it takes them a lot longer to get a bachelor's degree than they think it should,-and they spend a lot more money, and borrow a lot more money, and that type of thing. Very disappointing.

There are at least three sites where PIs or college faculty in departments that hosted the ATE said that their students in technology programs basically do not intend to transfer, and thus they rarely guide students to take general education in academic departments. At two of these three sites, no students had moved from technology to academic programs aiming at transfer. At one site, only six out of 620 students in the technology department that hosted the ATE had been taking classes in academic programs. In non-credit and workforce development programs, credits are almost entirely non-transferable. When we visited the sites, only one ATE-funded project focused intensively on developing programs that facilitated sending its students on to four-year institutions.

So far, the ATE program has begun to lay the groundwork for facilitating transfer by strengthening the academic content of technical courses. Nevertheless, articulation and transfer have not been important priorities for most of the sites. To some extent, this may reflect ambivalence among NSF staff and program grantees about the role that transfer

should play in the ATE. The whole ATE program was motivated by a conviction that there are a growing number of technical positions that can be filled by two-year graduates. Given these labor market needs and the complex institutional and regulatory coordination needed to facilitate transfer, it may make sense to focus on producing those graduates and economizing on the effort and resources needed to fight the transfer battles. The evolution of the ATE RFPs does indicate a growing emphasis on transfer, but in any case, the NSF staff and ATE grantees need to engage in a thorough discussion aimed at clarifying the role of transfer within the overall ATE program and the individual ATE projects and centers.

ATE-Industries Partnership Activities

All the colleges we visited have a history of working with industry. At six community colleges, partnerships between the ATE projects and industries were built on existing partnerships between the college and the industries. At four out of the six community colleges, the partnerships between the college and the industries were the primary drivers of applications for the ATE grant.

In all the sites we visited, the principal investigators of the ATE projects remarked on strong ongoing support from industries, saying, "The industries are with us," and "We wouldn't have been able to do this without industry support." Typically, this means that the industry participants provided important corporate resources: feedback on curriculum, part-time instructors for some of the advanced modules, technical assistance in the development of curricula, and donation of critical equipment. In addition, industry partners often provide work-based learning experiences for students, college faculty, and

high school teachers, hire students when they complete the program, and also participate in panels and workshops at events organized by the ATE-funded projects.

Industry involvement in ATE-funded activities include the following: (a) monetary and equipment contributions for the operation of the ATEs; (b) support with technical expertise for curriculum and course development and other ATE activities; and (c) job offers for students who come through the programs.

These supports are offered directly by individual companies and/or collectively through industry associations. Table 2.5 shows the type of supports provided by industries for each ATE-funded project.

Table 2.5: Type of Support Provided by Industry Organization and Individual Firms

College	Subject Area/ Technology	$ and Equip Donation	Technical Expertise	Career Opportunities
A[1]	IT	O F	O F	O F
B	Bio-tech	F	F	F
C	Paper & chemical		O F	O F
D	Construction	O	O	O
E	Paper, chemical & plastics	F	O F	F
F	Auto manufacturing		O	F
G[1]	Semiconductor		O	O
H[1]	Telecommunication	O F	F	
I	IT, telecom &all others	F	F	F
J[1]	Agriculture technology	F	O F	F

[1] Centers

Key

F Support provided by an individual firm

O Support provided by an industry organization

Industry Contributions

Seven out of ten sites have received cash contributions and/or equipment donations from either specific firm(s), industry organization(s), or from both. Contributions, ranging from several thousand dollars to about ten thousand dollars, are often provided through the community grant programs of corporations. At one ATE center, for instance, a partner industry contributed, through its corporate foundation program, about $200,000 in both cash and equipment. This contribution was managed through the Office of Resource Development at the college that hosted the ATE, and was reckoned separately from income that the college received from industry partners for such programs as job training or other customized instruction. This college took an aggressive and organized approach to securing contributions from business and corporate foundations. The representative of the Office told us that contributions are tax deductible. In 2001, the Office of Resource Development raised about $3.4 million.

Physical donations are usually provided from individual companies. They include lab facilities and computer-related systems and software, which are used for instruction at the ATE-funded projects. Equipment is sometimes brand new, but in most cases it is used. In the case that involved the most significant employer contribution among our sites, a new program was established entirely due to the equipment contributions of lab facilities from one company. We were told that the equipment is worth millions of dollars. Other cases include continuous retrofitting of equipment used for the ATE programs. At one ATE site, the industrial partners provided scholarships for students who took courses within the program initiated under the local ATE project.

Many ATE projects are working with advanced and rapidly changing technologies such as simulation, global positioning systems, and multi-dimensional animations. The equipment needed for these programs requires frequent updating. The needed equipment is changing rapidly even in more traditional areas such as construction technology. By providing equipment, industry partners can help keep ATE programs up to date.

Technical Expertise

Monetary and equipment donations have certainly helped the implementation of the ATE program, but support in the area of technical expertise is even more critical for the operation of the program. In seven out of the ten sites, representatives of partner companies were members of the advisory board of the ATE-funded projects. Through the board, these representatives provided consulting for curriculum and course development. In activities such as professional development and awareness programs, technology experts from partner companies usually provided technical advice and other assistance. In addition, opportunities for on-site experience, such as internship and occupational experience, were provided for the college faculty and teachers in partner high schools. Close interactions with industries were particularly crucial where there are not many faculty capable of teaching new technology fields. Thus, the participation of industry experts in the ATE projects provided the projects with substantial benefits.

Career Pathways

At five sites, companies offered future job opportunities for students who come through the ATE program. This is an example of concrete participation of industry in the development of education and career pathways. Career pathway building is made through formal or informal agreements of the college and industry, and sometimes with the high school. The strategy of the college is to convince potential college students and their parents that there is an education path leading to specific jobs. The ATE, along with the industry, presents applicants with the opportunity for employment by the industry when they complete the courses and requirements. This arrangement helps the community colleges as well as the ATE to increase student enrollment. For the participating industry, the arrangement helps to raise the probability of hiring new graduates with the skills that the industry needs.

Pedagogical Influence

What influence do partnerships with industry have on the overall educational and pedagogic objectives of the ATE program? To some extent, the answer to this question relates to the content of the programs that the industry partners promote. Are employers interested in skills that are specifically useful for their firm (referred to as firm-specific skills), or do they have a broader view focused on the general preparation of the industry's labor supply (general skills)? These two orientations are not necessarily contradictory but the broader view is more likely to be consistent with the educational vision that underlies the ATE program, which emphasizes general skills that provide an effective long-term educational base in a rapidly changing technological environment.

Table 2.6 shows the types of skills ATE-funded projects emphasized for partnership activities. At seven out of ten sites, the ATE practitioners, college administrators, and/or industry representatives reported that they place emphasis on the development of general or academic skills. These ATE projects, for instance, work to revise technical programs to include a greater coverage of basic math and science, as well as soft skills such as problem solving, critical thinking, and communication skills. One ATE-funded project called these soft skills "employability skills," necessary to perform any job in any industry. Staff members at another ATE site said that these are the conceptual skills that allow workers to apply what they learn in industrial settings.

Table 2.6: Type of Offerings by the ATE-Funded Projects for Their Industry Partners

Skill Orientation	A†	B	C	D	E	F	G†	H†	I	J†
General, industry-wide, or soft skill	X	X	X	X		X	X			X
Firm-specific skill	X	X	X		X		X	X	X	X

† Centers

At one site we were told that business people have realized that general education is as important as vocational training, and that they are more willing to invest in general skills. The college president mentioned that the trend is now moving away from the situation where workers would get reimbursed only for training relating to their job responsibilities. Companies, she said, have realized that it is important to raise the skills of the entire industry labor force, and that doing so will eventually benefit the company.

In fact, we heard several comments from representatives of industry organizations about the importance of general skills. They see the ATE-funded program as providing them with better-trained workers in the future. What often attracts them to the ATE-funded projects is the belief that the students who complete the ATE programs will be broader "generalists" who will contribute to the advancement of their firms. Industry organizations also recognize the importance to students of general skills preparation, since such preparation provides students with better opportunities for advancing their careers in the future. A representative from a semiconductor manufacturers' association remarked:

> [With] a broad base of preparation, [students] have choices upon exiting schools. I also still carry the message that semiconductor technician may be where you want to be now, but structure your academic program such that you can make that a stepping stone subsequently, if you choose to, so that after you finish with that two years, and you've been a semiconductor manufacturing technician for a couple of years, and all of a sudden, you decide, gee, I want to be a supervisor in this factory, then you'd take the, you know, the BAS degree or, for heaven's sake, I'm tired of dealing with this piece of trash that they send me, because it isn't engineered correctly, I'm going to school to be an engineer so I can design something.

But despite statements about the importance of general skills, some business representatives did look to ATE programs to meet the specific needs of their particular companies. At eight of our ten sites, ATE-funded projects offered skills geared toward specific companies. Their programs featured curriculum on specific workflow and production/manufacturing processes implemented at the workshops of specific companies and had limited instruction in academic skills. Further, they usually focused on contract or customized training, the contents of which were further tailored for the need of the individual companies.

At one project, the laboratory modules were developed to simulate actual operations used in a chemical processing company. An instructor hired for the lab training used to work at the company. With the representatives of the company, he developed chemical processing lab equipment by which students were taught exactly the process implemented at the company. The instructor reported:

> This model is exactly what is used at the company's workshop. Students learn here what they have to do when they work at the company. Their skills can be adopted right away at the shop floor...The company is very happy about it, because right after our students start working, they know how to open and shut the valve, when and how...the whole process of controlling.

At another college that we visited, contract training for a local mid-sized company was one of the major partnership activities. The program took an on-line format, and was designed to offer both certificates and an AAS degree. For a certificate program, there was literally no academic content. Even in the AAS degree program, the curricula were predominantly corporate-specific. Out of 68 credits to complete the course, academic-related classes consisted only of English composition with three credits, technical mathematics with eight credits, and elective social science with three credits. Basically, none of these credits was transferable to advanced degree programs. Furthermore, workers tended to avoid even these minimal numbers of academic-related classes. The industry representative said "To be honest with you, I'm not sure anyone took any type of English or social science yet through this program." In the development of this program, the ATE curriculum was carefully modified in order to make it as specific as possible to the company. The company representative said:

> They (ATE staff) spoke with us from the beginning to see what courses would work. They spent a few days, you know, going through the cell [of the course schedule], seeing our processes, our product, and all of that. And talked to several

> people to see, you know, what they could use for this program here, and then developed a program after that...

As a result, this program was basically structured to fit the technologies and workflow that the company used in terms of both the content and the substance.

For these companies, the ATE is more or less a program to which they outsource their corporate job training. When they establish a partnership with the ATE, they can lower training costs and avoid the complexity of conducting high tech training in-house. The primary reason for the companies to establish a partnership with the ATE is to lower their training costs, and they often do. A representative of a company that recently reduced their headcount said:

> A reason for getting out of in-house training and turning it over to schools is that training takes too much manpower away from core business. So we decided to form partnerships with the school for employee training...

In the meantime, projects that try to provide both academic skills and corporate specific training face the challenge of balancing these two approaches. One project placed significant emphasis on general education while receiving substantial technical, as well as monetary, support from individual companies. As this ATE project emphasized academic coursework in the first year of the program, the number of students from the companies has become minimal. We were told that the industry reduced its involvement because it perceived that its contributions would never pay off as long as the college does not offer contract-type training. This project was considering letting industry employees skip the first year academic courses and concentrate on coursework focusing on industry applications.

Where industry organizations were actively involved in the ATE activities, the ATE programs were more likely to emphasize the integration between technical and academic instruction. Industry organizations were also interested in a holistic approach for the development of curricula, by working with the college's instructional departments. In eight of ten sites, industry organizations were involved in the ATE partnership. Nonetheless, the participation of industry organizations tended to decline once a broad framework for partnership activities was established.

These examples illustrate the difficulties of aligning broad educational goals with the short-term needs of industry. Programs designed to prepare students for work in a specific company could, in principal, include the types of underlying academic skills that are fundamental to the ATE initiative. Alternatively, it would be possible to design accompanying courses or modules that provide broad academic instruction linked to the narrower skills taught in firm-specific courses, although we did not see this type of linked course in our sample. Our point here is that ATE grantees should keep in mind as they develop industry partnerships that the training interests of specific companies may not coincide with some of the underlying ATE goals.

The use of modern production technology may offer a resolution to the potential conflict between the specific skill needs of companies and the broad educational goals of the ATE. Many analysts and employers are convinced that a wider range of jobs requires the type of broad mathematical and scientific knowledge that the ATE is designed to strengthen. If this is the case, then workers educated in ATE-influenced programs may increasingly meet employer short-term needs, weakening the potential conflict of interest between the needs of specific firms and the ATE initiative.

The conflict may also reflect the lack of a consensus about the optimal academic content of technical instruction or a tension between the type of education that might prepare a worker for immediate productive work on the one hand, and preparation for dealing with changing technology or for future promotions on the other hand. The best education that prepares a student for work immediately after earning a certificate or an associate degree may still not be the most appropriate education for preparing a student to transfer.

Thus, whether the strong emphasis on partnerships promotes or slows that type of educational reform envisioned by the NSF depends on two factors: First, what the best mix of academic and technical skills is for the relevant technology; and second, whether the industry partners take a narrow view of their more or less immediate interests or take a broader perspective on the general strength of the labor supply in their industries. Our investigation suggests that both perspectives are present, although the involvement of industry organizations tends to strengthen the broader view.

Conclusion

ATE projects and centers have so far been successful in setting up activities with characteristics that match many of the objectives of the ATE initiative. They have particularly emphasized the development of new curricula and materials and, in most cases, reflect an emphasis on a strong academic content in technical education. ATE grantees have also created professional development opportunities to help faculty learn to use the new curriculum. Relationships to high schools have also been forged, and changes in the high school curriculum have been particularly noteworthy.

Although ATE staff members at the college level have developed many relationships with four-year colleges, at least among the sample that we studied, transfer has not been a priority. NSF staff members have recognized this reality and have increased the emphasis on transfer in the more recent ATE RFPs. Partnerships with industry have become a central and vital component of the overall ATE initiative, although there is a tension between underlying ATE educational goals and an emphasis on transfer, on the one hand, and some of the interests of the employer partners.

The next chapter examines the relationship between the ATE projects and centers and the colleges that host them. We explore the extent to which the progress made within the specific ATE activities has in turn influenced the colleges as a whole.

CHAPTER 3

ATE CENTERS AND PROJECTS AND THEIR COLLEGE HOSTS

This chapter analyzes the relationships between the ATE projects and centers and the colleges that host them. The NSF has clearly specified that while other institutions should be involved, community colleges are the lead ATE partners. But to what extent does the college as a whole become aware of and involved with ATE activities? The relationship of the ATE activity to the college—its effect on the college and how the college shapes the ATE activity—is central to the issues of institutionalization and sustainability and therefore to the long-term impact of the ATE program on the nation's education system.

The relationship between a college or a school and its externally funded activities is a fundamental issue in education reform. Grant-funded activities are by their nature outward looking, responding to the needs and demands of funders. They often have different rhythms, incentives, cultures, schedules, and standards than mainstream college activities. Soft money personnel have less security than college faculty but often have more resources available to them, and they enjoy a variety of benefits, such as travel and recognition, often not available to regular college faculty. Faculty members who take on soft money activities are pulled away from their teaching responsibilities, sometimes leaving their colleagues with extra burdens. This can all lead to resentment and misunderstanding. Some faculty members also develop cynicism about grant-funded innovations, which are seen as "reforms of the moment"; these programs will pass away soon enough when the money is gone, they believe. All these factors create disincentives

for the personnel working in soft money operations to engage with their colleges. The incentives push them to look outside of the college and to engage with other constituencies, both as sources of revenue—funders—and as targets for their output—customers.

This practice obviously has implications for institutionalization and sustainability. Projects or innovations that are fundamentally outward-looking and do not engage intensively with the colleges that host them are not likely to be incorporated into the ongoing processes and culture of their colleges, and thus are less likely to have effects on them. Sustainability of the projects would also likely be possible primarily through the continued availability of outside resources. Activities that do not engage seriously with the home colleges will most likely be output-, not process-oriented. On the other hand, the NSF has encouraged ATE grant recipients, especially the centers, to have a national or at least a regional perspective. So a weaker engagement with the home college may not be a weakness.[7]

What then is the optimal college-ATE relationship? We argue that this depends on the type of problem that the particular ATE project or center is designed to solve and on the barriers that exist in the normal operations of the country's community colleges and education system that give rise to those problems. If a college has already developed a successful curriculum for a new technology and the ATE's objective is to disseminate that curriculum, then intensive engagement with the college may not be necessary, or may even be a distraction. On the other hand, if college culture and organization prevent

[7] Throughout this report we draw distinctions between outward-looking activities and greater engagement with the college on the one hand and between output- and process-oriented strategies on the other. We draw these distinctions sharply to help clarify these concepts. Of course it is possible that particular centers and projects combine these different approaches, and, indeed, we find combinations in our sample.

the implementation of new curricula or pedagogy, then a substantive relationship with the college will be necessary.

But before making conclusions about what ATE staff members should be doing, we describe the relationships that have developed between the ATEs and their colleges. First we look at the administrative support and goals for the ATE. We describe the physical and organizational location of the ATE projects and centers within their colleges, and then discuss academic and occupational faculty involvement with ATE. We examine the interactions between the ATE activities and the credit and non-credit offerings of the colleges. Finally, we offer instances in which ATE projects or centers have engaged with their college to begin to bring about some important organizational changes.

ATE-College Relationships Overall

Our analysis of the impact of the ATE program on STEM instruction at community colleges is based on interviews with administrators and faculty in the various college divisions, including the academic, occupational, continuing education, and workforce development departments; as well as an examination of the relationship between ATE activities and materials and the courses and programs of the college.

The Emergence of the ATE Project or Center

In almost all cases, the ATE project or activity was built on existing activities and programs at the colleges. This is hardly surprising since a staff with no experience in a particular area would be unlikely to qualify for a grant. In many cases, the college had

already put substantial resources and effort into building centers, often with its own buildings or programs. Two ATE projects and one center were incorporated into centers that either existed or were being established before the ATE funding. Three centers and two projects built on preexisting programmatic thrusts that involved partnerships with industry. Another project in our sample emerged from a cluster of loosely related projects and programs receiving both public and private funds.

Thus, the ATE activities emerged from and were embedded in existing activities of the colleges. Understanding the environment from which the ATE emerged is crucial for our efforts to analyze the ATE-college relationship because, in most cases, the characteristics of that relationship are determined by the pre-existing activities from which the ATE projects or centers emerged.

Administrative Support and College Mission

Our interviews with the college presidents, as well as with senior administrative staff, showed that they were usually very supportive of the ATE-funded projects. Generally the receipt of the NSF grant was a matter of pride. The PIs and administration at five colleges stated that being awarded an NSF grant helped to secure other grants. Once the college gained NSF funding, state and other agencies became more interested in their activities.

There is particular support of the ATE activities when the objectives of the ATE projects are aligned with the general mission of the college or the specific strategy of the college leadership. In many cases, the president became interested in applying to the ATE because he or she perceived that the grant would contribute to the overall strategic

objectives of the college. Table 3.1 shows the initiators of the projects and indicates the support extended to ATE-funded projects by the president and senior administrative staff. Assessment of the level of support is based on such indicators as the level of knowledge among the college top administrators about the ATE-funded objectives and activities, the involvement of the college administrative offices in grant-seeking and management activities, and financial support. A strong existing system for grant-based activities was positively associated with presidential initiation of and support for the ATE.

Table 3.1: Support by the College Administrators

College	(1) Project Initiator	(2) Support by College
A†	President	Very supportive
B	Principal Investigator	Not very supportive
C	PI and President	Very supportive
D	Principal Investigator	Supportive
E	President and PI	Very supportive
F	College Administration	Very supportive
G†	College Administration	Very supportive
H†	College Administration	Very supportive
I	PI and College Administration	Supportive
J†	College and PI	Very supportive

† Centers

The president and senior administrators of all of the community colleges we visited said that they started thinking about the grant primarily to respond to the needs of the

community, as well as their local industries. In the selection of specific technologies, and in the organization of the project framework, a primary objective for the colleges is to work with the area industries to serve the community better. The ATE projects are sometimes initiated to counteract the decline of a local industry. In three colleges we visited, the major industries in the communities have downsized significantly in recent years. This provided an impetus for the presidents and administrations of these colleges to initiate close contacts with various local industries, and to facilitate the ATE program operating in collaboration with those industries. These presidents and administrative groups have exercised strong leadership from the start, from conceptualization to the specific writing of the grant. They played a major role in selecting specific technologies for the ATE by using their knowledge of the community as well as the needs of the local economy. The PIs, and also the local business community, clearly state that the active involvement of, and strong support by, the college presidents have been key factors in developing the ATE activities.

One project was an integral part of a much larger initiative undertaken by the college. This initiative involved the development of a new urban technical high school focusing on an underrepresented population in an urban area. A philanthropist who initially funded about a half of the development costs made this effort possible. The president described the role of the NSF as a "catalyst," a "vehicle," and "the final piece of the puzzle" for the building of the new high school, particularly by playing a leadership role in the development of a curriculum framework for the new high school. Specifically, this ATE project developed curricula for teaching technical skills for the construction industry. The basic framework was to develop a 2+2+2 pathway through a partnership

with the area high school and a university. Shortly after the start of the project, an inter-governmental cooperation agreement was developed among the college, the area high schools, and the four-year institutions, led by the city council and major industry organizations.

In one center, the college and the faculty PI initiated an agricultural technology project. Prior to receiving the NSF funding, the college invested in the facility and technology lab, and recruited the PI from a nearby college. Thus, once again, the college saw the ATE funds as a crucial part of a broader initiative. This strong sense of ownership of the ATE program by this college resulted in a substantial amount of investment in the program. The college has invested more than ten million dollars in the agricultural center in general, and about one and a half million in the equipment used for the ATE in particular. The college also provided administrative support for the operation of the ATE as well as support in resource development for additional grants for the center.

There were also colleges that showed a lower level of organizational commitment to the ATE-funded projects. Less intervention by the administration in the ATE can give the project more flexibility in its operation. However, faculty members with teaching duties who are also the main actors of the ATE may suffer from an overly heavy workload. At one research site, a lack of administrative support for grant seeking or for project operation resulted in the project PI's being overwhelmed by work. This was one reason why the PI did not apply for a renewal of the grant.

Several of the presidents of other colleges in our sample also saw the ATE activities as contributing to broader organizational goals. At one site, the president

considered acquiring the ATE resources as part of an overall strategy to increase the college's emphasis on technology. Another president thought of the ATE as an indication of the college's commitment to outside funding. Others saw the NSF support as a way to strengthen ties with local industries.

When the top administrators of the college have a strong sense of ownership of the ATE-funded activity, they are more likely to share with the ATE their existing resources, such as facilities, faculty time, and administrative services in grant development and business support. Administrative commitment to the ATE activities does not necessarily define the nature of the ATE-college relationship, however. Supportive administrators could see the ATE either as a set of activities that are engaged with the internal organization and operations of the college or as a more or less separate set of activities oriented outside of the college. Thus, other evidence besides administrative support is necessary to identify the characteristics of the ATE-college relationship.

Location of the ATE-Funded Projects

The physical and organizational locations of the ATE projects and centers reflect how the colleges position the program within the college itself. The program location affects how, through whom, and to whom the ATE-funded activities are disseminated. In order for innovations developed by the ATE activities to be integrated into the college, communication between the ATE staff and the non-ATE college faculty is important. To be sure, cooperation and interaction are possible even at a distance, but shared physical space facilitates communication, particularly informal communication, between the ATE

and the rest of the college, and such communication smoothes the progress of disseminating the ATE-funded activities. Physical as well as organizational distance impedes inter-departmental interaction. Moreover, the physical and organizational location of a project indicates something about the administration's perspective on the role of the activity within the college.

Table 3.2 summarizes the physical locations of the ATE projects we visited. Four of the programs were situated in an independent building. Two projects were located on campuses that primarily provided occupational/vocational education and training. Both campuses were more than 20 miles away from the main campuses that housed academic programs. Four projects were located in buildings that offer occupational and vocational education, which were separated from general education buildings. Corridors connected two of the buildings, and the other two were within walking distance of other buildings on the same campuses. None were located in an academic building.

Table 3.2: Physical Location of the ATE-Funded Projects

Location	A†	B	C	D	E	F†	G	H†	I	J†
Independent Building/Office	X	X					X	X		
Voc/Occ. Campus					X				X	
Voc/Occ. Building			X	X		X				X
Academic Building										

† Centers

Information about the organizational location of ATE projects and centers is summarized on Table 3.3. Three of the four centers, and four of the projects, were independent of the other divisions and managed directly through higher administration. Only one of the six projects that we studied was located organizationally within an academic, transfer-oriented department. Three of the six projects were housed in technology-related departments. Included in the group of technology programs are: Technical and Industrial Division, Division of Industrial Technology, Technology Division, and Agricultural Technology Program. They were occupational or vocational divisions that generally prepared students to work after the program, and usually offered the Associate of Applied Science (AAS) degree, certificates, and/or a specialist diploma. More of these programs had recently been named "technology programs" and were differentiated from traditional vocational or occupational education. These programs aimed at placing a greater emphasis on the use of technologies and on the conceptualization of technological applications (see Savage & Sterry, 1991, and Sterry, 1987, for more detail about "technology education").

Two projects were located in the Department of Workforce Development. Included in the workforce development department are the Division of Business and Industry and the Continuing Education and Workforce Development Division. These divisions were organized primarily to serve industries through such programs as customized/contract training and consulting. Most of the programs offered were short-term, non-credit, and/or certificate programs.

Table 3.3: Organizational Location of the ATE-Funded Projects

	A†	B	C	D	E	F	G†	H†	I	J†
Independent	X						X	X		
Workforce			X						X	
Technology				X	X	X				X
Academic		X								

† Centers

Thus, some of the ATE initiatives were organizationally or physically distant from the rest of the college. At these colleges, although the college presidents and senior administrators expressed strong support for the ATE projects, the projects remained somewhat peripheral to the core activities of the college, particularly the academic, transfer functions and in some cases even the occupational, credit-bearing programs.

This separation is illustrated by the experience at one ATE center, which was situated in an independent building across the street from the most closely related department. Upon the establishment of the ATE center, three engineering faculty

members were assigned to work almost entirely for the center for three years. They thus moved from the department location to the building across the street. The dean of the engineering department described the department location as "this side of the street" while calling the ATE program building as "that side of the street." He then suggested that such isolation had brought about a feeling of distrust between faculty members in the same department in different sides across the street. He characterized the situation thusly:

> There's a street cutting us in half that has become a very problematic thing spiritually, emotionally, operationally, physically, any way you want to put it. What happened over the years is that there has developed sort of a feeling of...I'm searching for the right word...a feeling of elitism, a special, set-aside, set-apart, kind of feeling. So the conversations that have gone on [at the ATE program] relative to curriculum and equipment and everything have been kept apart from the other eight, nine, or ten faculty members upstairs on this side of the street. As time went on, that rift, I believe, just became stronger and stronger. That's not a healthy thing.

At another college, the president said that "I am in the position of explaining that the money for the project is not the same as the faculty money," implying that the faculty does not want the college to subsidize the ATE. In another college, a faculty member, in the department in which the ATE is located, said that the ATE imposes a "big penalty" on the department because the department loses faculty headcounts while they take release time to work for the ATE. This faculty member also said that he was not interested in participating in the ATE project, explaining that the ATE program is "fine for somebody else," but he does not want it at his college.

Although this type of resentment was not typical of the colleges in our sample, it illustrates the potential tensions that result from quasi-independent, grant-funded activities.

The ATE Relationship to College Faculty and Instruction

In the initial stage of grant development, the commitment of the college president and senior administrators is important to acquire the grant and to set up the organizational framework that rolls out the ATE. Once the project is funded, however, the administrators usually turn the project over to the PI and/or the director of the ATE. The college administrations are not involved much in the day-to-day activities of the ATE, which occur more with the college department that hosts the ATE, or with the departments with which the ATE is collaborating. At the stage of implementation, support by the college faculty at the department level increases its importance.

Collaboration among faculty members, particularly from different departments, is important for reasons other than facilitating the dissemination of the ATE-funded activities. As more of the college faculty and departments are involved in the ATE, incorporating the strengths of different programs can enhance the ATE program of instruction. For example, input from academic faculty on basic math and science, from technology faculty on technical or applied subjects, and from faculty in workforce development on business and industry, make the development and implementation of the ATE-funded instructional materials effective for both work-bound and four-year program-bound students. In the following sections we first report the impact of the ATE program on credit-bearing programs, including occupational/technology and general education programs. We then examine the impact on non-credit-based, workforce development programs.

The ATE Relationship to Credit-Bearing Instruction

For an examination of the impact of ATE on college faculty in credit-bearing programs, we focus on the participation of faculty members in the major ATE-funded activities of curriculum development and dissemination, professional development, and career awareness. We focus on how faculty members in technology/occupational programs and those in general education, particularly basic mathematics and science programs, are involved in these ATE activities.

Table 3.4 shows the PIs in terms of their status as faculty members, and if they were faculty, whether they taught in credit-bearing programs. It also shows whether the PIs were from the academic, technology, or workforce development areas. At five of our ten sites, the PIs belonged to departments that offered credits and associate degrees. One of these five PIs was in an academic program; the other four were in technology/occupational programs. In the other five sites, the PIs did not belong to college programs that offered credits. At four of these five, the PIs had been hired specifically to manage the ATE operations. In College C, the PI was a faculty member, but in the workforce development division, a division that did not offer a degree program itself.

Table 3.4: Faculty Status of PI

College	Faculty Status of PI
A†	Not faculty
B	Academic/Credit-bearing program
C	Economic Development
D	Technology/Credit-bearing program
E	Not faculty
F	Technology/Credit-bearing program
G†	Not faculty
H†	Technology/Credit-bearing program
I	Not faculty
J†	Technology/Credit-bearing program

† Centers

For non-faculty PIs, or for PIs in non-credit programs, involving faculty members of credit-bearing programs is critical in order for students to earn credit in ATE-related courses and for those courses to be part of degree programs. To explore how the ATE has been able to involve faculty members from outside the ATE, we looked at the involvement of faculty of technology/occupational programs, then of academic programs. We further examined the involvement of high school teachers and four-year faculty in partner institutions.

As Table 3.5 shows, the participation of technology/occupational faculty members in the ATE activities was pervasive. Except for one project where the ATE was

managed in an academic program, technology faculty were involved in almost all the ATE activities. This was true both for the ATEs that were located in technology departments and for those located elsewhere. Whether or not the PIs were faculty members, and whether the faculty PIs were in technology departments or not, the ATE projects were collaborating extensively with the faculty of the technology departments.

Faculty members of technology departments are often the co-PIs for the projects. The ATEs are particularly successful in gaining the participation of technology faculty for the development of the ATE curriculum as well as its implementation. The ATE projects and centers call these faculty members "subject-matter experts," and expect them to support the dissemination of the ATE instructional materials into the existing technology curriculum. This designation promotes the use of the ATE curricula and materials by the technology/occupational faculty.

Table 3.5: Technology Faculty Participating in the ATE Activities

Activities	A†	B	C	D	E	F	G†	H†	I	J†
Curriculum Development	X		X	X	X	X	X	X	X	X
Teaching the Curriculum	X		X*	X*	X	X*	X	X		X
Professional Development	X		X	X	X	X	X	X	X	X
Awareness and Career Pathway Development	X		X	X		X	X	X	X	

* The program is designed to be taught by the faculty, but they have not begun to do so yet because the program is currently being implemented only in high schools.

† Centers

Most technology faculty we interviewed told us that the ATE is useful for their departments. They often used the program as a resource for their instruction as well as professional development. At one college, faculty members said that the center activities "are a complement to what we are doing in our department," "are helping us to gain cutting edge in technologies," "are allowing students to use the technology in advance," and "are enabling us to exchange information with community colleges that the project is partnering with." Faculty also said "through innovative instruction, students feel that they are enrolled in a superior school," and "the college has a great pride in such innovative ideas and activities."

What about the relationship between the ATE program and academic programs? Table 3.6 shows the involvement of academic faculty in the major activities of the ATE. The participation of general education faculty was far less common that that of technology faculty.

Five projects reported that they interacted or tried to interact with faculty of academic programs. At four of these projects, academic faculty members provided input for the substance of the ATE curriculum during its development. There were two colleges that had a strong emphasis on academic education; at one of these, the ATE program was located in an academic department. In that case, the academic faculty alone developed the curriculum with the industry partner. At another college, there was also strong involvement by academic faculty in the development of the curriculum. In two additional cases, the academic faculty did provide some input, but did not work directly on curriculum.

While academic faculty were involved in curriculum development at four sites when we visited, the curriculum was used in the academic program at only one of the sites. Thus, the ATE materials represent forms of the occupational or technology curricula, but not the academic curricula.

We observed the same situation in professional development. Faculty members in academic programs were involved in professional development at only two colleges. At college C, only one academic faculty member was involved with the project. Professional development is a continuous activity through which the initiative of the ATE is disseminated to, and imbedded in, the rest of the college. Thus the low involvement of academic faculty in ATE professional development weakens the potential effect of the ATE on the academic programs and departments. The low level of involvement of academic faculty also weakens the extent to which ATE-based courses are transferable to four-year schools since the academic programs and the relationship between academic and occupational programs at community colleges are crucial for transfer.

The involvement of academic faculty is also thwarted because they are often skeptical about the content of technical courses in general. At five colleges, at least, we have identified a sense of concern that the ATE project did not have a strong enough academic content. The Vice President of Academic Affairs at one site described the ATE: "There's an institute in there [the engineering technology] that's mainly training. Most of the stuff is mainly training." She went on to state:

> Every certificate and degree on offer has to have certain academic courses. We try very hard not to have a certain English course for this major and another English course for that major. Everybody needs to take freshman college English, composition and rhetoric...What has caused trouble is that engineering technology creates their own little courses in order to bypass regular courses.

Resistance to the ATE program among academic faculty was particularly strong in colleges with a strong liberal arts tradition. In some cases, the ATE program was located outside the traditional instructional unit because of anticipated hostility from academic faculty. One college had an ATE in the Business and Industry Division, and the ATE maintained a clear distance from the academic department. The president of the college pointed out that if the college inclined to industry-oriented instruction, there would be strong resistance from college faculty:

> We do not have industry-focused programs. This is our approach. Even in electrical technologies, engineering, whatever, they are all AS degrees. There is very strong tradition here...this is a history founded by a founding president of this college. There is a sense of this will be a liberal arts college. ...There is no customized program. If we have, there is a lot of resistance. We don't do that.

Thus, given the liberal arts tradition of this college, it is not surprising that the ATE project was set up within the workforce development division—that is, independent of the academic department. Indeed, at the time of our visit, most of the project's activities, partly in anticipation of resistance from college faculty, were in local high schools.

At another college with a strong liberal arts tradition, the ATE program was set up in an academic department, but had difficulty balancing the interests of the industry partners, who wanted more focused occupational education, with the department's commitment to a more extensive liberal arts content. Partly for this reason, the PI did not seek additional funding when the NSF grant ran out.

The ATE Relationship to Non-Credit Programs

The previous discussion focused on two major findings: occupational faculty were actively involved in most of the major ATE activities, and academic faculty had only marginal roles and were sometimes skeptical about ATE-funded projects. Our investigations of the ten sites further revealed that the ATE-funded activities were often located in non-credit-oriented workforce development programs and that ATE involvement with non-credit education was increasing.[8]

For example, curriculum developed at one college had primarily been used in contract-training programs for incumbent workers. At another college, the ATE project was administered by a regional technology network center. The goal of the president of this school was to turn over to this center all of the customized training performed at the college. At yet another college, the ATE project had been moved from the division of engineering technology to the workforce development division, which focuses primarily on contract training, and short-term, non-credit, and certificate-type programs.

Several factors encourage colleges and PIs to locate the ATE projects in workforce development divisions with an emphasis on short-term programs and contract training. These reasons included greater flexibility, better control over revenue, and efforts to avoid potential conflict in colleges with a strong liberal arts culture.

For example, at the college that changed the organizational location for the ATE from the engineering technology to the workforce development division, the president cited tension with the academic culture and work schedules as a major reason. Moreover, according to the president, as a result of rapid technological changes and increasing

[8] Workforce development programs are designed to serve industry clients primarily, offering contract type education and training, short-term certificate type programs, and sometimes consulting. When the programs offer credits and degrees, they do so through arrangements with other programs within the colleges.

competition, the college needed to respond more quickly to the needs of industry: "The college has to keep close business connections, and to provide timely services," the president said. Also, more industries are demanding certificate programs and flexible applied programs tailored to specific technology or industry needs. The separation from the credit programs allowed the ATE to act flexibly to meet industry requirements.

Independence from credit programs gives ATE projects more flexibility in pricing, since tuition for credit programs is often regulated by the state. Independence also facilitates the retention of any revenues from sales within the ATE project or center. These types of issues were cited by four presidents from our ten sites as reasons for their interest in locating ATE activities outside of the core, credit-bearing divisions.

Finally, because of the applied curricula that the ATE is promoting, colleges with a strong liberal arts culture tend to have greater difficulty locating the ATE in the traditional academic part of the college. At two sites, the organizational separation of the ATE activities allowed the colleges to maintain their focus on liberal arts and work closely with industry through economic development and customized training programs.

Examples of Innovative ATE-College Relationships

Our research demonstrates that administrators and PIs can use the ATE to effect important changes within their colleges. Here we describe three cases in which the college and ATE staff worked to strengthen the relationship between academic and occupational instruction, to bring together different parts of the college, and to move towards a curriculum that integrates technology, academics, and employability. By bringing about organizational changes, these colleges were working towards better

institutionalization of the ATE initiatives and towards a process-oriented, in addition to an output-oriented, conception of reform.

At one college, the establishment of an ATE center coincided with the development of a cross-departmental institutional structure designed to facilitate innovative activities. The college, for example, recently set up new structures for departmental deans. Before, there were two senior deans for academic and vocational programs, respectively. Under these senior deans, there were eight department deans. The college took away the position of the two senior deans, and the eight departmental deans report directly to the vice president of academics. This organizational change has helped to facilitate communication and exchange of information across departments.

The college also set up an "Operation Team." This team consisted of six people, each of whom had a specific focus on college operations, including secondary school relations, human resources, continuing education, business services, and governmental relations. In their respective areas, the members exercised operative management across the college departments. This system helped to prevent the organization from forming a hierarchical rigidity that often hampers innovative thought and action. This college's emphasis on innovative activities seemed to be understood and acknowledged by the faculty. Almost all the faculty members we interviewed mentioned that the college permitted them to take risks, encouraged innovative activities, and paid for such activities. So far, this ATE center is viewed as an integral part of the college, and the PI was working to collaborate with academic faculty such as the chair of the department of mathematics. The president and the vice president of academic affairs supported such efforts.

At another college, the vice president for academic affairs viewed the ATE project as an important component of a long-term strategy to promote applied learning approaches throughout the faculty, including academic faculty. First introduced in the early 1990s, this approach met considerable resistance. At that time, the college set up a committee focused on teaching reform that served as a semi-formal communication channel through which the curriculum concepts embedded in the ATE program were disseminated to the rest of the college. This committee did not have power to change, modify, or restrict the teaching content. But it was established under the VP of academic affairs, and assumed a workshop format to improve the faculty's teaching skills. The ATE PI had been the co-chair of the committee for the past number of years. A faculty member who was participating in the ATE module development was one of the initiators of the committee. In this committee, student-centered, hands-on and applied curriculum was promoted, and learning modules developed by the ATE project were introduced as a part of the curriculum concept.

The academic curriculum imbedded in occupational education has now been widely accepted, and faculty members were preparing to teach the curriculum when we visited. Also, the college was considering the application of the technology with which the ATE was working to other programs, including nursing, geology, graphic information systems, and data management. Here, the ATE grant provided important support for the education strategy pursued by the PI and the vice president. They were then able to use an interdepartmental structure to promote their strategy.

At a third college, the ATE project emphasized high school curriculum development that combined technology, employability, and academic content. In order to

implement the ATE curriculum, the ATE staff promoted inter-departmental collaborations. The ATE PI and the program manager worked closely with the educational research and development institute managed by the joint administrative teachers' union. They exchanged information with each other, and worked together on professional development. The project also worked with the academic department on instructional assessment. Curriculum assessment ensures that the ATE-funded curriculum works well with the existing college program.

The PI said that these collaborations were realized through informal, day-to-day communications among faculty members. The curriculum development process also promoted communication and collaboration among institutions and departments. First, the ATE curriculum action team, led by a university partner, designed the curriculum. Then, the community college faculty and high school teachers refined the curriculum based on their actual teaching environment. Finally, the refined curriculum was returned to the ATE team, and then returned again to the faculty and teachers with comments and suggestions. Throughout this process, particularly during workshop meetings, the participants actively exchanged ideas and experiences. Although the workshops ran almost all day on Saturdays, they were very well attended.

Conclusion

The ATE-college relationship is as complex as the ATE program itself. ATE projects and centers pursue a wide variety of objectives in the context of different technologies and economic conditions. Curriculum development and dissemination do not necessarily call for deep engagement with the home college, while program reform

and attempts to integrate academic and occupational instruction must be based on patient and long-term work with faculty and administrators from different departments and divisions of the college.

Are there generalizations that we can make based on the information that we have gathered from our sample of four centers and six projects? In nine of the ten cases, the ATE was operating with enthusiastic support from the college administration. In some cases, the college was investing substantial resources in the center or project, or had provided substantial resources to a broader program that laid the groundwork for the ATE grant.

In most colleges, the ATE projects have been successful in engaging the technical faculty in the development of ATE curricula and products, and, in many cases, in the use of that material. Since, as we argued in the previous chapter, the ATE curricula in general has strong academic content, the engagement of the occupational faculty implies that ATE curricular reforms are spreading through occupational and technical divisions of the colleges.

We did find a tendency for colleges to move ATE activities towards workforce development divisions oriented towards shorter-term instruction and customized training. This trend, to the extent that it is generalized, will complicate efforts to strengthen the transfer opportunities for students using ATE curricula. Colleges that do lodge their ATE activities in workforce development divisions are responding to strong incentives that encourage this type of distance from core credit programs. To the extent that specific ATE objectives require closer engagement with those core programs, NSF staff, college administrators, and PIs need to plan their activities with those incentives in mind.

Only one of our ten sites was located organizationally in an academic department. In general, academic faculty were drawn on as experts for the purposes of curriculum development rather than as potential users of materials or participants in program redesign and development. Moreover, the academic faculty often resisted collaboration with the ATE or the use of the ATE curriculum, because some academic faculty members believed that the ATE threatened the liberal arts culture. Therefore, for the most part, the ATE has brought about reform of occupational but not academic education. Once again, to the extent that ATE goals can be advanced by greater engagement of academic faculty, the NSF and PIs will need to take account of the cultural and organizational features that discourage that engagement.

We did find some cases in which the ATE PI, in collaboration with college administrators and some faculty, had made progress in bringing about broad changes. Two factors appear to be important. First, all of these cases involved formal and informal structures that brought together individuals from different departments, divisions, and even institutions (four-year colleges, unions, high schools, or business representatives). Second, in these cases, the NSF provided additional resources and prestige to reforms that were already underway.

Thus the optimal ATE-college relationship depends on the problem that the ATE is trying to solve. Depending on their goals, successful programs can operate at the margins of a college or can be integrated into a college's core activities. Some of these goals are, not surprisingly, more difficult to achieve than others. Strategies aimed at bringing about significant organizational and cultural change within the college face particularly difficult barriers. The ATE resources and assistance can be used to

implement those strategies, but college administrators and ATE PIs must take account of the barriers that they face.

CHAPTER 4

THE SUSTAINABILITY OF THE ATE PROGRAM

Since the ATE funding is limited, the sustainability of ATE activities is a central concern. The ATE program was never expected to provide permanent funding for any particular center or project; nevertheless, the NSF expects that the innovations and reforms promoted and encouraged by the ATE projects and centers will continue after the federal funding ceases.

Since the first ATE grant was awarded in 1994, 517 grants had been awarded to community colleges as of July 2003. At that time, 230 grants were listed as currently active. Grants for ATE projects last up to three years, grants for ATE centers allow for four years, and both can be renewed for an additional three years. Among active grants, some of the ATE projects and many of the centers have received an extension of their initial awards. Nevertheless, many projects and some of the centers have either ceased receiving NSF funds or have experienced significant reductions in their funding levels.

Qualities of Sustainability

ATE activities can be said to be sustained if they continue beyond the end of NSF funding. Although this definition seems straightforward, the concept of sustainability is complex. What exactly should be sustained? PIs of ATE centers, in particular, might want to perpetuate the existence of the center itself, and, thus, in anticipation of the ending of the NSF funding, the center staff would look for alternative resources to pay the ongoing costs of the center. But the center—the organizational entity—is not the

same as the activity that it was set up to carry out. The staff of the ATE projects might also try to perpetuate the particular activities funded by the NSF. For example, perhaps the project established a marketing campaign to enroll high school students in the college or professional development workshops for teachers and professors. Sustainability would mean that the marketing and workshops would continue after the funding expired. But sustainability could also be achieved despite the disappearance of the specific activities funded by the ATE. For example, formal relationships between colleges and industries established with NSF resources may continue informally, or teaching strategies, developed and disseminated by ATE centers, might simply become part of the normal operations of the colleges, embedded into the understanding of how a community college should go about its business. Indeed, this type of incorporation may be considered the most profound form of sustainability: fundamental changes in college culture and methods of operation take root as the ATE grant and its explicit activities reside only in the memory of college veterans.

Thus, an assessment of sustainability, or the extent to which a particular ATE project or center is sustained, must be based on an explicit understanding of what that project or center was trying to achieve and, just as important, what barriers stand in the way of achieving that goal. As we have emphasized throughout this report, the nature of the barriers that the ATE is trying to overcome is fundamental to the success of strategies for sustainability. In many cases, they will determine whether the ATE activities should be continued explicitly or whether they should be absorbed into the normal activities of the colleges.

If sustainability does imply the long-term continuation of particular ATE activities, then we need to determine how those activities should be funded and whether they should be integrated into the host colleges or should operate as more or less stand-alone self-sufficient organizations oriented towards the outside. Once again, the way that the project continues depends to a large extent on the ATE goals and the barriers that the ATE project or center is trying to overcome. If what is needed is pure curriculum development due to rapidly changing production technologies and associated skill requirements, then an outward looking, more or less independent organization might be most appropriate, although one would expect that at least the college that hosts the center ought to adopt that technology. On the other hand, if what is needed is a structural or organizational change within the college, or stronger partnerships between the college and businesses or other educational institutions, then a closer, more integrated relationship with the college would seem to be essential. In other words, does the project need to focus on removing barriers and establishing an environment in which the normal functioning of the education system will produce desired results, or is the environment already appropriate, and the creation and dissemination of materials is what is needed? These distinctions correspond to the concepts of process-oriented solutions and output-oriented solutions that we discussed in the introduction.

These considerations lead us to reconsider issues of sustainability: Is the need for the ATE grant permanent or transitory? What makes a difference to the length and amount of the funding from project to project? What specific resources are available, other than ATE grants, to sustain projects, and how can projects secure such resources? How can a fund-based project be integrated into the mainstream of the institutions or

transformed into an entrepreneurial, self-sufficient project? What are the specific approaches that help?

In this chapter we use information from our case studies to explore the problem of sustainability. We ask first whether the centers or projects are working towards the explicit continuation of the ATE activities after expiration of the grant and then, if they are, how they are doing so, including their sources of potential funds. Second, we ask in those cases where there are plans for continuation, whether the activities will be integrated into the operations of the college, or whether program PIs are working towards outward-looking self-sufficiency.

Moving Toward Sustainability at the Sites

At the end of the grant period, all colleges that have ATE projects face similar questions: Should the activities that have been developed under the ATE grant be continued, and, if so, how should they be continued? First, it is possible that the project was not successful and therefore should not be continued. The ATE program encourages innovation and risk taking and it is to be expected that some of the activities funded under the program will not be worth continuing. This is a matter for the evaluations of the individual projects, and in this report we do not make judgments about activities. Nevertheless, this is the first question that should be asked by the NSF and by grantees when considering sustainability.

Second, it is possible that an ATE grantee needs more time to achieve its initial goals. All ATE projects state specific goals and objectives in their proposal to the NSF. At the end of the grant period, and as a result of NSF requirements for the final project

report, all projects review the extent to which their objectives have been attained. Based on the ten sites we visited, both the ATE PIs and the college administrators expressed that the duration of the ATE grant, up to three years, is not long enough to implement and institutionalize their objectives and goals. One senior college administrator remarked:

> Community colleges are a big machine and move very slowly. It takes a long time to turn our ship around. It's easy with a grant to say, "here's this money, and in three years institutionalize it." What would be more practical is to say, "here's this money and it's for five years." Three years is too rapid for the budgeting process in our system...It is really a five-year cycle to truly make something part of an institution. This is academia, we do not move rapidly.

The initial period of the grant is usually spent establishing the basis of the project, which generally involves skills analysis, curriculum and professional development, and partnership building. Accordingly, such important activity goals as curriculum dissemination, continuous professional development, and industry and career pathway awareness activities are often left unattained. Projects whose objectives have not been fully attained consequently face the question of whether, without the ATE grant, they should keep working to meet their objectives.

Professional development and awareness programs to interest and recruit students have also been underway. But these activities require a longer duration in order to attain visible results. For instance, in projects that focus on a 2+2+2 pathway development, the first grant period is almost entirely used for curriculum and professional development, partnership building, and awareness programs. It is only from the third year on that the community college enrolls students into the pathway.

With two exceptions, all the projects have activities still to be attained. Among those projects whose activities have not yet been attained, two were in the early stage of

the grant cycle, and two had experienced discontinuity of major activities due largely to the replacement of initial PIs. In a short-term sense, four other projects or centers had accomplished their initial goals, which in most cases were the creation of new curricula. But in each case there was a sense that critical work remains to be done, either in updating or disseminating the material.

The other four projects needed to continue to work on product updating and dissemination, student recruitment, and/or professional development. Two of them had attained their major objectives, and the activities have now been implemented in the existing college program. For both projects, the ATE grants were allocated for the development of instructional materials. Therefore, the implementation of the developed materials was not under the ATE grant, but rather it was under the college program management.

However, these are short-term considerations and in many cases the NSF has extended initial funding to allow completion or extension of initial plans. But once the curriculum is developed or the initial partnerships are established, what will happen in the long run? In the ten sites that we studied, two of the most important activities included working with high schools to develop pathways and recruit students, and creating and disseminating curricular materials. Below, we use developments in these two broad activities to discuss the issue of sustainability.

Example: Recruitment of High School Students

Three of our sites, at the time of our visits, were working primarily with high schools or high school students. In two of the three cases, over the long term, the program

organizers expected to begin working within the colleges once the high school programs were established. Not surprisingly, both of these projects built on previous Tech Prep programs and relationships.

What are the problems that these programs were trying to solve? These projects worked with manufacturing and construction industries and, in all three cases, representatives were having trouble recruiting young people into technical occupations due to a supposed 'aura of decline' that surrounded these industries. In addition, the occupations had changed in recent years, now requiring, in the opinion of educators and employers, a stronger academic and technical education.

Thus, in every case, the high school curricula developed by the projects emphasized combining applied studies with strong science and mathematics—the integration of academic and vocational education. The ATE-related high school courses were designed to achieve several goals. First, they upgraded the technical education in the high schools, thus presumably strengthening the preparation of high school students. Second, they provided knowledge about those industries and the skills needed for them to high school students, thereby overcoming some of the students' misconceptions and lack of information. Moreover, in each case, the development of the curriculum involved collaboration between high school teachers, community college or university professors, and local business people. Professional development workshops were also organized to help teachers learn how to use the new curriculum. In one case, there was some resistance among high school science and mathematics faculty who refused to move to a new curriculum, although in that same program, those high school teachers who did use it were enthusiastic. But overall, by altering the curriculum and building social networks,

the ATE programs changed the environment that gave rise to the original problems, and thereby promoted sustainability of the innovation.

The most ambitious of these three programs was contributing to the creation of a new technical high school that explicitly integrated academic and vocational education (and prepared students for the statewide academic competence exams). This high school had millions of dollars of support from a local foundation, although the president of the community college with the ATE grant stated that the college had been a catalyst for the whole project, and that the ATE participants had been instrumental in the development of the curricular framework for the school. The college's role would seem, at least in principle, to be an ideal use of NSF funds: the leverage of resources to bring about a structural change that promotes an environment that alleviates the underlying causes of the initial problem. In these cases, the problem was the shortage of students interested in working in certain occupations and a less-than-ideal educational system for preparing those who might be interested.

Presumably, once high school teachers become accustomed to teaching the ATE project courses, they will continue to do so without the extra spur of an NSF grant. If the courses are successful, then the related professional development and perhaps the curriculum updating (reinforced by relationships built with the industry representatives) could be absorbed into the normal operations of the schools. Whether curriculum will be adequately updated as technologies continue to change is perhaps an open question, probably depending on the speed of the change. With the possible exception of the program that was working to build a new high school, the grantees were not explicitly trying to guarantee that the curriculum and professional development would become

embedded into the activities of the high schools—that is, they were not explicitly trying to achieve process-oriented reform in the high schools. Nevertheless, in each case, the grantees intended to continue their work after the end of the NSF grant, with either additional NSF money or funds raised from elsewhere.

At the time of our visits these three projects were primarily focused on developing high school curricula and working with high school teachers; four additional sites did some work with high school curriculum and teachers. In most cases, high school activities were one part of a menu of ATE activities, often involving workshops lasting from one to five days to familiarize teachers with new curricula. ATE funds paid for these workshops and in some cases actually paid high schools to participate. It is difficult to predict the future of these activities. If they were significant enough to become part of the regular activities of the high schools, then there is a chance that they would survive the end of the grant. On the other hand, grantees tended to be seeking additional funding to perpetuate the activities, or they hoped that high schools would eventually pay for their services, although the latter seemed unlikely, particularly in those cases where high schools were currently paid to participate.

One interesting approach involved the development of videos and promotional materials to provide information to high school students about the attractive employment opportunities in technical fields. If this strategy could bring about a widespread attitude shift in high schools, then we could say that its effects would be sustained after ATE funding ended. The materials, though, would involve more or less continuous updating, and the program grantees did intend to seek additional funding to do that.

Therefore, overall, the projects and centers pursued three broad strategies to strengthen the pool of young recruits for the relevant technical fields. First, they tried in various ways to get information to high school students about the benefits and opportunities of working in these fields. Second, they tried to develop and clarify the educational pathways necessary to prepare for those occupations. Third, they worked to strengthen the preparation of young people through curriculum development and professional training at the high school level. The approaches most likely to have a long-term effect are those that change the structure of the high school and the experience that the students have—that is, a change in the environment that engendered student skepticism originally. Since ours was not a study of high schools, we cannot make an independent judgment about the effectiveness of these strategies. It would seem, though, that more intensive approaches would have a greater chance of sustainability. Working to develop a curriculum framework for a high school is more likely to have long-term effects than developing a single course. Working with high school teachers to develop curriculum is more likely to have this effect than inviting them to a one-day workshop. Having students learn about the industries and occupations through classes and contacts with employers is more likely to provide comprehensive information than a video or other promotional materials. While the more intensive approaches may be more costly, we suspect that they have more of a chance of becoming part of the regular operation of high schools in the future than do cheaper, simpler approaches.

One issue that has not received much attention concerns changing the incentives for students to enter these fields. The assumption appears to be that the incentives are there, but that the students are not aware of them. To be sure, the NSF and its grantees do

not have much control over the compensation of technicians, although many of their industry partners do. The community colleges do, however, have influence over the structure of educational opportunities. If students are skeptical about the payoffs to careers in some of these fields, it would seem important to make sure that the community college programs to which they are being recruited can be the basis for even more educational attainment that would lead to more lucrative employment. But as we pointed out in a previous section of this report, many of the programs in the ten sites that we studied did not emphasize transfer and, indeed, there was a trend away from embedding ATE community college curriculum in transfer-oriented programs.

Example: Curriculum Development and Program Improvement

Seven of the ten sites that we studied were developing new instructional materials. While the other three sites were not creating new material, they were engaged in modularization and dissemination of existing material, and, as one of the co-PIs put it, "magnifying the impact of existing curricula." The NSF makes a distinction between materials development and program improvement. The ATE's evaluator defines program improvement as "comprehensive curriculum development and associated improvement that results in the production of credentialed cutting-edge, skilled technicians." Indeed, analysis of changes in the ATE RFPs suggests that the NSF has been increasing its emphasis on program improvement, although the programs that we studied were started before this shift in emphasis became apparent. So in the cases that we studied, it is convenient to think about a continuum from pure materials development to more thorough program improvement. In any case, almost all of the centers and projects that

developed materials also engaged in some type of professional development, which is an important element of program improvement. At the same time, the distinction between materials development and program improvement does have implications for the nature and characteristics of sustainability.

What is the future of the materials and curriculum development and program improvement activities? To answer this question, we must first ask what problem these projects and centers were trying to solve.

Six of our sites were working with relatively new or rapidly evolving technologies: information technology, semiconductors, simulation technologies, global positioning technologies applications, telecommunications, and biotechnology. And at four of them, the ATE grant provided funds for centers or projects that were already working in these areas, having been funded internally or already having received other grants. The ATE funds allowed the colleges to expand their activities, but more importantly, the funds allowed the colleges to disseminate the materials that they were developing to a broader audience. At two of the sites, for the most part, the material was already developed, and, at least initially, these projects or centers focused on disseminating that material. In this case, the "problem" was that existing material was not widely used and the solution to that problem was broader dissemination.

How will these activities need to be sustained and how might that happen? Once the curriculum is widely used, then any additional need for dissemination probably depends on the speed at which the technology changes, thereby causing a need for updated curricula. Our interviews suggest that program grantees did not have a good sense of how often materials would have to be updated.

At most sites, though, new curricula and materials were actually being developed. Why did curricula not already exist? In some cases, it was because the technology is very new and curricula were simply not available. At two other sites, the curriculum development was focused on traditional industries that had experienced important technological change in their production processes. Once again, the extent to which curriculum development activities will need to be sustained depends on the frequency with which the material needs to be updated. If occasional and moderate updating is adequate, then the task could be carried out within the normal processes of curriculum development. If frequent and large changes are necessary, then sustaining the usefulness of the material would require special funding, either from the NSF or other sources. One possibility that some centers have considered involves working with a commercial publisher, a topic we will return to below.

In addition to creating new materials or curricula, most sites also conducted professional development activities associated with using that new material. Within our ten sites there was a range of intensity of these efforts. Professional development can involve short-term workshops designed to familiarize faculty with new curricula or it can involve more intensive efforts aimed at making more fundamental changes in pedagogy and the use of materials. Moreover, the more intensive the activities, the more likely that community college faculty will engage seriously with the processes at the home college. That is, a purely materials development project can be more outward-looking and focused on dissemination, while a serious effort at program improvement will involve working with the program at the home college. At our sites, professional development activities tended towards the less intensive end of this continuum.

In any case, what would sustainability of a program improvement effort look like? At least in the host college, if the ATE project or centers bring about significant program innovation that is established within normal, ongoing processes, it is not clear that additional resources would be needed, unless the new program features generate greater costs. It is still too early, though, to make a judgment about whether this type of integrated sustainability will take place.

We have emphasized that initial NSF discussions about the need for the ATE program reflected the belief that necessary innovations in education for up-to-date technicians can only take root in the context of deeper changes in the structure and culture of the college. But as we pointed out earlier in this report, most of the projects and centers we visited were not designed to change the curriculum development *process* or the structure of the colleges. That is, ATE activities in our sample sites were more likely to be engaged in output-oriented rather than process-oriented reform strategies. While the curriculum being developed at most of these sites did incorporate math and science more than similar curricula did in the past, among those programs that were focused on community college level courses (seven of our ten, since three were working mostly with high school programs), all but one were aimed primarily at either non-credit or technology programs with weak access to transfer. Thus, while technical courses were enhanced with additional academic content, the innovations were being incorporated into a more or less traditional organizational structure that preserved the distinctions between academic and technical instruction. As we showed earlier, some academic faculty at our ten sites have been involved with the development of ATE materials and curriculum but few used that material themselves.

Most colleges that set up ATE projects and centers had not set out to use them to bring about deeper changes. Nevertheless, if the current environment in the colleges is not conducive to the types of program improvement that the ATEs *are* trying to bring about, then there may be implications for the sustainability of those reforms. It may be that a change in the structure of the college could facilitate the institutionalization of those innovations. But if the environment is not supportive of the program development innovations, then sustaining them over the long run may require more effort and ongoing resources. Therefore, ironically, activities that are easiest in the short term may be the ones that require additional resources in the long term.

Finding Additional Resources

Even if the ultimate goal for some ATE activities might be full institutionalization and incorporation into the ongoing processes at the colleges, there are many circumstances in which the specific activities of the ATE entity ought to be continued. Dissemination is perhaps the most obvious. Dissemination of successful approaches is not a normal function of a college. Perhaps a state system might provide resources for in-state dissemination, but it would be in the interest of the NSF to have valuable products disseminated across state lines. Moreover, innovations directed at institutionalization may take several years to become rooted, so ATE PIs may need additional funding simply to consolidate their successes. Rapidly changing markets and technologies may require such frequent updating of curricula and methods that normal processes of curriculum development and dissemination may simply not be able to keep up. Where will the

colleges acquire the resources needed to continue their activities after the expiration of their grants?

We have identified the following four types of significant resources available or potentially available to fund ATE activities:

- Other external grants.
- Funding from industry.
- Income from the sale of ATE-funded products.
- Community colleges that host the ATE program.

Other External Grants

Most of the ATE-funded projects we visited received external funds in addition to the ATE grant and, as we have pointed out, in many cases they already had substantial outside support when they received their initial ATE grant. Support includes federal grants from the U.S. Department of Labor, the U.S. Department of Education, and other agencies. Many projects received state grants related to school-to-work. The administration of these funds varies. In some projects, the college departments that hosted the ATE, such as the workforce development division or the division of engineering technology, received the grant, using some portion of the money to operate the ATE-funded activities. In another case, the community college that hosted the ATE was not the fiscal agent for the external grant; rather, the ATE accessed the funds through a partnership with the educational organization that received the grant. The college's Tech Prep program, for instance, often provided substantive support for the operation of the ATE, particularly when the activities of the ATE involved pathway development with

high school partners. Finally, in some cases, the NSF has been willing to extend funding or has provided extra funding for specific projects for an existing ATE center. For example, one center received an NSF grant to disseminate materials developed under the center funding.

Seeking additional funding is therefore an important strategy in extending and consolidating work accomplished with NSF resources. Several PIs in our sample commented that the NSF grant gave them credibility when seeking other resources. Securing additional funding is a sign that other funders recognize the value of the effort. There is a potential conflict with the college, however, if ATE grantees are seen to be competing with other college programs for the same foundation resources. Thus, it is important that the ATE be integrated into the fund raising strategies of the college.

Funding from Industry

As discussed in previous chapters, relationships with industry are important to ATE projects, particularly because of the advanced technical nature of the subject areas. Once the ATE grantees acquire the relevant knowledge and skills, they can serve industry by training current or potential workers. Where ATE grantees can offer services tailored to the needs of a specific industry, the industry is willing to pay the cost of the services. Among the projects we studied, one in particular received significant support from industry, ranging from the contribution of instructional equipment to the provision of corporate instructors to teach the ATE-funded curriculum. According to the PI, this support will be sufficient to maintain ATE-funded activities without NSF funds.

Too much reliance on industry funding may carry risks, however. First, industry resources are extremely sensitive to economic conditions; training funds are often cut when markets contract. Second, there may be some tension between the broad educational goals of the ATE program and the specific interests of local businesses, a tension that may be accentuated when economic conditions deteriorate. Third, as with grant seeking, ATE staff may be in competition with other parts of the home college for attention and resources from local businesses. This potential problem is diminished if the ATE activities are well integrated into the plans of the college.

Income from Product Sales

Several of our sites have secured some resources from the sale of the materials or services that were developed using NSF funding. Yet managers of centers in particular do not view sales as a way to replace the bulk of the NSF funding. Rather, sales of materials might account for 10 or perhaps 20 percent of a typical center budget. Sales of professional development services have perhaps been more problematic. In some cases, grant funds were used to pay faculty and teachers to participate in professional development. Not surprisingly, it has been more difficult to interest potential clients in the same activities when they have to pay for them.

Some sites were exploring commercialization of developed materials through for-profit publishers. This appears to be an attractive option and it fits into a venture capital perspective on NSF funding: NSF provides funding to develop materials in new or rapidly changing fields and, once colleges and publishers see that they are useful and successful, commercial interests can take over and update, market, and distribute the

materials through regular commercial channels funded by sales revenues. But while this scenario may be an effective way to disseminate materials, it cannot be counted on to provide significant institutional support for ongoing operations of a center or large project. Moreover, the sites taking this approach were still struggling with the details, not the least of which was problems with intellectual property. If professors developed the material for the ATE center or project, which then sold that material to a publisher, how were the professors to be compensated? In two cases, we found some resentment among professors about this compensation.

Support from the Host College

Fund raising, industry support, and sales, taken together, do create substantial opportunities for additional resources. And indeed, there are several advantages to working towards greater independence from the colleges.

- The ATE can have an outward-looking management and operation, aiding the expansion of its market outside the college to include industries and other educational partners.
- The ATE has greater financial flexibility by not belonging to the credit part of the college, since income from non-credit programs can be retained free from the control of general education funds.
- The ATE has greater flexibility in program offerings as well as in the markets it serves, such as various non-credit-oriented programs including certificate, specialist, and contract training programs.

- The ATE can have close and flexible communication with industry to update technology and have input into activities such as curriculum development and professional development.
- Greater separation, particularly in colleges with strong liberal arts traditions, avoids conflict with faculty who want to maintain that tradition and believe that it will be threatened by too much emphasis on serving the needs of businesses.

Nevertheless, most PIs do not believe that they can develop their ATE activity into a self-sufficient organization and therefore look to the home college for support as well. Indeed, at least eight of our ten projects and centers were drawing on college resources even during the period of the grant. Release time and administrative support paid for by the college were the most common, but at five sites, the college was actually contributing funds to supplement the ATE activities.

As the end of the NSF grant approaches, not surprisingly, interest in college resources has risen. For example, in one college, this change occurred after the center director retired, and the college found that the center would not be able to sustain itself without the strong involvement of the college. College administrators reported that the ATE, under the previous PI, was neither able to cooperate with the college staff nor to establish a self-sufficient operation. The center, when we visited, was under the direct supervision of the Vice President of Academic Affairs, and was undertaking a major restructuring. While the previous PI had come from outside the college, college faculty were given PI and co-PI positions. The restructuring further involved various area experts within the college, including VPs in grants, administration, enrollment, and economic

development, as well as deans from the schools of business and information, engineering, technologies, math, and science. Whereas the center had offered only a non-credit program, the restructuring team was working to align the ATE curriculum with degree programs. The college is paying the cost of the restructuring. The center will receive NSF funds for two more years, but as that amount declines, the college will be contributing an incrementally greater amount. In sum, in this particular case the college has intervened and is making serious efforts to integrate the ATE within the college in order to sustain the center.

At another college, the ATE center developed new instructional modules that were delivered to partner colleges and industries, independently of the college. While the main market is thus external, the center's interest in serving the college that hosts the ATE has increased. The PI of the center recognized that selling ATE products only to the external market would not pay the entire costs of the service, and thus will not sustain the center. In particular, an industry that worked closely with the ATE has been declining recently, which significantly reduced the expected income of the center. In addition, the NSF funds are tapering off. To counteract these declines in revenue, this center gained an increasing financial commitment from the college. In turn, the center will serve the college by providing faculty with instructional modules at no cost. Some of the services provided for the college, such as educational research programs and faculty development workshops, are activities not initially part of the center's goals. Thus, in this case, the center's financial needs are serving as a force for greater integration with the college.

The home college may then also be seen as a customer for ATE materials and services. In five projects, curricula and other instructional materials developed through

the NSF grant have been used in the colleges' regular courses. So long as these materials are used and maintained as part of the college's regular programs, the college could, in effect, sponsor the activities. In addition, projects focusing on pathway activities with high schools could be seen as generating a flow of students to the community colleges. But permanently supporting curriculum development staff in a particular occupational area is probably beyond the means of even large colleges, and the home college does not have any reason to support a dissemination operation.

Colleges may also have reputational interests in supporting NSF-sponsored activities. We have already mentioned that the presence of the ATE may help in other fundraising. Some presidents make good use of the positive publicity generated by the ATE. ATE support can raise the profile of the college in the local business community, among local taxpayers, or in the state legislature. Therefore, it may make sense for the college to, in effect, lose money on an ATE center or project if it leads to additional revenues from these other sources.

Certainly almost all of the PIs we interviewed recognized that the home college was a crucial source of resources and that it would be unlikely that any significant activity could be sustainable without support from the college. Moreover, the financial relationship between the college and the ATE has important implications for the nature of the activities carried on by the ATE project or center and by whatever entity survives the end of NSF funding. A strong focus on achieving independence and self-sufficiency naturally pulls the attention of the ATE staff away from the home college. And, in order to avoid competing with other parts of the college in local fundraising and the development of partnerships, ATE staff may seek resources nationally rather than locally,

further reducing the focus on the local college. Of course, especially for the centers, the NSF wants a national focus, but we have argued that comprehensive program improvement, and especially deeper organizational and cultural change, requires intensive engagement with the home college. Thus, financial involvement by the college may signal a realization that the ATE activities have made a deeper contribution to the college. One job of the ATE grantees may be to show the college administration that the innovations funded and encouraged by the NSF will broadly benefit the strength and effectiveness of the college as a whole. If the college administration views the ATE center or project as a peripheral activity that can stay as long as it pays for itself, or if the administration sees it as a cash cow, then it is less likely to be perceived as a vehicle for bringing about significant program reform or comprehensive organizational or cultural change.

Conclusion

Sustainability of ATE activities cannot be analyzed or studied in the abstract. The optimal path and characteristics of sustainability depend fundamentally on the objectives of the activity. In particular, we have emphasized the importance of understanding the problems and barriers that gave rise to the need for an ATE initiative in the first place. Why have the normal processes of curriculum development and dissemination, faculty preparation, and student recruitment not resulted in an optimal technical workforce? A variety of issues—the need for dissemination and packaging of existing material, an absence of appropriate material or curricula, weaknesses in program design, and more fundamental problems in the overall college culture and organization—all imply a

different relationship between the home college and the ATE activity and a different profile for sustainability.

One view of the overall ATE program is that it is an attempt to create materials and programs of study that either do not exist now or that exist in a form not appropriate for current technologies. In Chapter 1, we referred to this perspective as an output-oriented view. For the most part, the sites that we studied were pursuing output-oriented strategies and, in most cases, they have made significant progress along these lines. The question for sustainability, therefore, is whether they will need to continue to create or update these materials and programs in the future or whether the innovations can be absorbed into regular college processes. The speed of technological change is an important determinant of the need for revision. Dissemination will probably need a longer-term strategy than materials creation. But in many cases, the underlying task will not be complete by the end of the planned NSF funding; additional resources will be necessary either from sales of materials, industry, other outside funders, or from the college itself. Most of our sites were engaging in, or planning to engage in, some combination of these activities and in some cases all four. We have pointed out advantages and disadvantages to each of these sources of funds.

A second way to think of the ATE is that it is a strategy to change the underlying environment in higher education, so that regular educational processes will be able to produce the necessary types of programs and technicians. We referred to this in Chapter 1 as a process-oriented view. For the most part, the sites that we have studied have not yet explicitly pursued this broader view of reform, although efforts to do so have increased. Moreover, as we have pointed out, an analysis of changes in the RFPs—the shift from

materials development to program improvement and the increased emphasis on transfer and articulation—suggests that they are also moving towards a more process-oriented approach. Bringing about organizational and cultural change is much more difficult than producing curricula and programs, but if change is successful, then sustainability would be more likely to take care of itself. Although additional resources might be necessary for updating purposes, those changes would be developed within a more supportive environment.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The Advanced Technological Education (ATE) program of the National Science Foundation is now ten years old. The fundamental goals of the program are to increase the number of technicians in science, technology, engineering, and mathematics (STEM) fields and to improve the quality of the education system that prepares them. The U.S. Congress and the NSF have explicitly focused this program on the nation's two-year college system, although participating community colleges are expected to forge partnerships with industry, high schools, and four-year colleges and universities.

This report is based on field work at four ATE centers and six ATE projects. In this chapter we first briefly summarize the accomplishments of the ATE projects and centers that we studied. We then review and apply the conceptual framework that we developed to study the institutionalization and sustainability of ATE activities. Finally, we identify some areas where the overall ATE initiative could be strengthened in the future, and end the chapter with recommendations.

Before we present our conclusions, it is important to emphasize that while we sought to choose a variety of centers and programs to study, the sample is small and not necessarily representative. Further, the ATE program itself is evolving, so our observations refer to the situation that existed when we made our visits between 2000 and 2002. Moreover, most of the centers and projects that we visited had been planned and initiated in the mid- to late-1990s. Therefore, our conclusions may not necessarily reflect the situation with more recent activities.

ATE Site Accomplishments

So far, the ATE program has had several significant accomplishments. Many of the projects and centers have focused on the development of new curricula for scientific and technical fields. Strengthening the academic content of technical instruction is one of the central tenets of the ATE program, and the curricula developed by the centers and projects that we studied did indeed have strong academic content. Some of the sites we studied were also experimenting with modularized curricular strategies that potentially can provide more learning benchmarks and flexibility to a student's educational program. ATE grantees have also had success in engaging technical faculty in the development of the ATE curricula and, in many cases, technical faculty have used the ATE materials in their classes. The participation of these faculty combined with the strengthened curricula is evidence that the ATE is making progress in reforming technical education in community colleges. In addition, some academic faculty members have also participated in the development of the new curricula. This type of participation can begin to breach the traditional barriers between technical and academic education in the colleges.

Some of the sites that we studied have made general progress in interdepartmental collaboration, working to break down traditional barriers. Two conditions appeared to facilitate these developments. First, colleges that sought to obtain these objectives developed both formal and informal structures that brought together faculty and administrators from diverse parts of the college. Second, in the interesting cases that we found, the goal of ATE sites was to enhance reform strategies that were already in place;

college faculty and particularly administrators saw the NSF funding as a tool to help bring about reforms that they were already pursing.

ATE principal investigators (PIs) and their staffs have also garnered strong support from industry. Businesses have provided resources, equipment, advice, internships, and jobs for graduates. Many ATE grantees have worked closely with employers in the creation and design of curriculum, skill standards, and professional development, providing the grantees with access to knowledge about the latest technological developments and skill requirements in the industries. Industry organizations can play a particularly important role in supporting more wide-ranging educational reform as well. While individual firms are often focused on their specific skill needs, associations usually have a broader conception the nature of necessary skills. Thus they are more likely to be supportive of efforts to strengthen the academic content of technical education or to integrate academic and technical instruction.

The ATE initiative has promoted significant inter-institutional collaboration. ATE PIs have overseen the development of relationships among the community colleges, high schools, and four-year colleges. Work with high schools among the sites that we studied has been particularly impressive. Grantees also made use of faculty from four-year colleges for curriculum and professional development. These relationships, if they are sustained, can strengthen the environment in which STEM education takes place.

Conceptual Framework and Findings of the Study

A central goal of this study was to analyze the ATE projects and centers with respect to the institutionalization and sustainability of ATE-initiated or funded activities.

We developed a conceptual framework to examine these issues. Analyzing the relationship between the colleges that host the ATE programs and the programs themselves, we suggested that there are two broad strategies. One is based on an outward-looking strategy that does not engage intensively with the college, such as focusing on creating and disseminating new curricula to a broad range of educational institutions. The other is based on more intensive engagement with the college that hosts the program, perhaps through programmatic, organizational, or cultural change within the college.

Considering sustainability, we also suggested alternative approaches. First was to determine whether sustainability is desirable or necessary. Certainly some ATE projects may not have been successful, and therefore should not continue. This is a normal and expected part of a broad program designed to encourage risk taking and innovation. Second, some ATE activities may be aimed at solving one-time problems and, once they are solved, activities can cease. For example, a new technology arises for which there is no curriculum. Once that material is prepared and disseminated, additional resources and effort may not be necessary.

In cases where the ATE-funded activities ought to be continued, we suggested two broad alternatives. In one, outside funds and extra effort continue to be necessary even after ATE funding has ceased. In the second, the ATE activities lead to internal programmatic or organizational changes within the colleges, so that the ATE "innovation" in effect becomes a standard procedure. In that case, new outside funding would be less necessary.

In addition, we summarized some of these strategic alternatives by developing the concepts of output-oriented and process-oriented perspectives. As noted, output-oriented

approaches focus on using the ATE to promote the curricula production and professional development. Process-oriented approaches, in contrast, focus on changing the programs and college organization in order to create an environment that will, as part of normal operations, produce the appropriate quantity and quality of technicians.

Output- and process-oriented approaches also relate to institutionalization and sustainability. Output-oriented strategies most likely result in outward-looking relationships to the college (i.e., innovations are less likely to be institutionalized) and require continued funding and effort for sustainability once NSF funding ends. Process-oriented strategies are more likely to involve close engagement with the college, and if they are successful, are less likely to require continued external funding or special efforts. So far, ATE projects and centers have put most emphasis on output-oriented strategies. The development and dissemination of new curricula and efforts to recruit high school students could all be considered output-oriented approaches. Nevertheless, some of the projects and centers have initiated the elements of process-oriented strategies. The involvement of academic faculty and the creation of interdepartmental structures can potentially break down the traditional academic/occupational divide. The development of partnerships with outside businesses and educational institutions can potentially change the environment in which curricula are developed, disseminated, and taught. Some of the most interesting process-oriented strategies can be seen at the high schools with which some of the colleges in our sample worked. At some of the high schools, in contrast to the colleges, ATE activities were focused on the core academic science courses *as well as* on the occupational or technical courses. Despite these examples, process-oriented strategies were less developed than output-oriented approaches.

In our sites, for the most part, the ATE was implemented within the traditional structure of the community college, not challenging the tension between technical and academic organization and instruction. While technical faculty were active both as users and developers of ATE material, academic faculty were primarily involved with curriculum development, and even their involvement there was often not extensive. Except in some high schools and one community college, the ATE projects and centers in our sample had not influenced the content or pedagogy of academic courses. Thus, the ATE has promoted a reform of technical courses rather than a more broad-based integration of academic and technical instruction throughout the college. We also found that transfer was not a priority in the ATE projects and centers that we studied. While ATE technical curricula had stronger academic content, in many cases, those courses were still not transferable. Moreover, we noted a trend towards short-term or non-credit courses, and these types of courses are usually not transferable either.

We have emphasized that over the long run, process-oriented approaches are more likely to institutionalize ATE reforms. Thus, those centers or projects that have concentrated primarily on output-oriented strategies may have a more difficult time sustaining their gains. Sustainability is certainly possible without institutionalization, but in most cases it will require additional outside funding to replace the NSF resources when the ATE grants run out. ATE grantees at the colleges have pursued a variety of strategies to secure additional funding, including appeals to industry, foundations and other sources of soft money, and the colleges that host them.

It is not surprising that output-strategies have been more common. First, the internal structure of colleges, particularly the division between academic and technical

instruction, is long-standing and well established. Moreover, there is no consensus within the faculty, particularly academic faculty, at community colleges that this division should change. It is easier for ATE staff at a college to avoid this conflict and focus their attention on changing the content of technical courses or even short-term or non-credit courses, where they are likely to meet much less resistance. Even the enthusiastic involvement of industry may limit the depth of reform. While industry associations tend to support broader educational innovations, the short-term firm-specific interests of particular employers may not always be consistent with the broader educational goals of the ATE. We found both types of influences among the partnerships developed by the centers and projects that we studied. In addition to these factors, the structure of the ATE program, the system of RFPs, and the granting of soft money to colleges also tends to create incentives for output-oriented rather than process-oriented approaches. As we have pointed out, soft money operations within educational institutions tend to operate at the margins of those institutions, and are therefore relatively weak tools for bringing about internal substantive or organizational changes.

This does not mean that the ATE centers and projects cannot bring about process-oriented reforms. Indeed, in our sample, we have seen important progress. It does mean that the NSF and its contractors face significant barriers to achieving broader, structural changes. It is not surprising that during the early years of the program, ATE PIs did not start with the most intractable problems. There was plenty of important progress to be made without challenging well-established organizational structures and cultures. But now with a ten-year track record of widespread reform of STEM education, the NSF may have the opportunity to shift the emphasis. Indeed, this appears to be what is happening

In the last few years, the NSF has, through the design of its RFPs, sought to strengthen reforms that would be considered process-oriented. In particular, it has strengthened provisions encouraging more attention to transfer and articulation and program reform (as opposed to materials development). The RFP-specified focus of the regional centers, the latest type of center provided for by the ATE program, explicitly calls for efforts to change programs and systems. Thus, we would expect to find more widespread attempts to pursue process-oriented strategies among more recently established centers and projects.

Recommendations

The ATE program is designed to achieve a set of objectives concerning the quantity and quality of STEM technicians in the country, and it is designed to achieve those objectives by funding activities anchored in community colleges. In principle, the NSF would like to see the innovations and reforms that it funds institutionalized and sustained once ATE funding ends. We have argued, though, that the optimal level and nature of institutionalization and sustainability depends on the underlying problems that the ATE activities are trying to solve.

Increased Problem Specification

Thus, our first recommendation is that in planning for ATE projects and centers, the applicants and the NSF staff need to be specific about the problem that they are trying to solve, or more specifically, about the circumstances that stand in the way of solutions and improvements. The education system creates and disseminates instructional

materials, organizes professional development, and develops partnerships with business and other educational institutions. Why are these normal organizational processes not adequate without additional ATE resources? Is it due to the emergence of a brand new technology for which no material has yet been developed or because the type of education needed is not easily incorporated into existing institutional structures and cultures? Different causes imply different solutions, and the nature of those solutions will in turn influence the most appropriate level and nature of institutionalization and sustainability.

The following is a list of possible problems:

- There are insufficient appropriate instructional materials.
- Existing materials lack adequate academic content.
- There are no instructors who can develop appropriate instructional materials.
- There are instructional materials, but no instructors to teach them.
- There are instructional materials, but no distribution channel.
- There is a shortfall in the number of students who come to technical programs in the college.
- Too few technology/occupational students go on to advanced STEM programs.
- General education programs do not connect theory to application.
- The organization or cultures of colleges thwart the introduction of innovative material or pedagogies.

Planners may need to go beyond even these explanations. Why are instructors not available? Is the cause deficiencies in the education system or perhaps in the incentives? Are high school students not entering programs because they are not adequately prepared

or because they do not believe that they represent good opportunities? If the latter is their perception, is it accurate or a result of a misunderstanding? Regardless of the nature of the problems and barriers, a detailed and specific statement of them is the first step to designing a lasting and effective solution.

We have argued that early NSF documents discussing the need for the ATE program indicate a conviction that both output- and process-oriented strategies are needed. Yet the RFP-initiated reform model that the NSF works with tends to create more incentives for output-oriented than process-oriented strategies. Thus, it is not surprising that we found that output-oriented approaches predominated in our sites.

Design Incentives to Investigate and Promote Broader Programmatic and Organizational Innovation

The first recommendation suggests this second one. The NSF staff, ATE applicants, and operators of current ATE projects and centers need to be aware that the underlying characteristics of the initiative tend to promote a particular type of solution (i.e., an output-oriented approach). In many cases, this approach may be the most appropriate solution, but special provisions will need to be made in situations where the NSF and college staff judge that a different type of approach is needed. As we have pointed out, a trend towards more flexibility is already evident in the evolution of the ATE RFPs, but the ATE operators at the college level also need to make special and conscious efforts to achieve process-oriented changes when necessary.

We have provided some examples, from the projects and centers that we studied, of interesting efforts by ATE staff members to engage more intensively with their host

colleges. In some cases, these efforts have sought to bring about deeper change within the college, particularly through breaking down the divisions between academic and technical education. Administrative support is obviously crucial. Interdisciplinary teams and organizational reforms that combine related academic and technical programs within organizational categories are possibilities. Gaining support from four-year colleges can also help to create an environment more conducive to cooperation between academic and technical faculty in community colleges.

Partnerships with business are crucial, but ATE operators need to be aware of the potential conflicts between the broad educational goals of the ATE and the firm-specific interests of individual employers. Thus, ATE staff members need to work closely with partners to emphasize the importance of a long-term strategy. The involvement of industry organizations is particularly important since these groups tend to have a broader view of the needs of industry than individual firms. However, our experience suggests that the interest of industry organizations is difficult to sustain.

The NSF ATE grantees, and their partners in four-year colleges and industry, need to engage in a broad discussion about articulation and transfer to baccalaureate-granting institutions. The optimal solution would be a two-year degree that would provide the immediate skills sought by employers and also serve as the first two years of a bachelor's degree. This education model requires a willingness of educators to rethink the nature of prerequisites for upper division courses and of employers to take a broad view of the types of skills that they are seeking. The ongoing discussion of modern innovative workplaces, sometimes referred to as high-performance work organizations,

suggests that the tension between immediate work preparation and preparation for additional education should be diminishing.

The ATE annual PIs meeting, the conventions of the American Association of Community Colleges (AACC) and the League for Innovation in the Community College, and other specially organized meetings all offer opportunities for NSF staff and program operators to share experiences. These meetings have been an excellent opportunity for college personnel to see material produced by projects and centers. We suggest that ATE grantees also be encouraged to present discussions about how they have approached achieving their goals. For example, sessions at conferences or special meetings (or perhaps listservs) could be organized to exchange information about successful collaborations between technical and academic faculty, overcoming barriers to program reform, lessons for working with four-year institutions, experience with commercialization of ATE material, approaches to raising money once ATE funding ends (if necessary), and identifying underlying systemic barriers to successful sustainability. A videoconference on achieving sustainability organized by the Western Michigan University ATE evaluation team in February 2003, and a subsequent conference on the same topic held in Phoenix (organized by the Maricopa Advanced Technological Education Center (MATEC) in March 2003, are examples of efforts to promote collective learning about successful strategies.

New Research Studies

Finally, our project has also suggested a research agenda. We have argued that the division between technical and academic instruction in colleges is an important barrier to

more thorough reform of technical education. But attempts to break down these barriers often meet resistance from faculty, staff, and college constituencies that are convinced that these divisions serve important purposes. Similarly, improving articulation and transfer is made more difficult by disagreements about the amount of academic or general education courses needed for terminal occupational degrees versus transfer-oriented programs. This dissension suggests a broad research agenda to explore the best ways to combine academic and technical instruction, both to meet the needs of the job market and to prepare students for subsequent education. This is a research agenda that should also be of interest to other programs within the NSF.

Our report clearly suggests the need for a research project tracking the experience with ATE activities after the end of, or significant reduction in, NSF funding. Studying a sample of post-funding projects could provide useful findings. Eventually, post-funding studies of centers might be possible, but now, most centers are still receiving some level of funding. Tracking the experience of centers as funding declines would still be useful, though. Studies of post-funding projects would identify which activities, if any, continue, explore the nature of the relationship between NSF-funded projects and centers and the colleges (institutionalization), and identify alternative funding sources. A related study of commercialization of ATE-developed curricula is also necessary. Commercialization is one obvious route to sustainability; therefore a thorough understanding of the process is crucial. The Western Michigan University evaluation team is currently planning a study of sustainability that will meet some of these objectives.

Finally, the NSF and ATE grantees need to continue to work towards a better understanding and measurement of the outcomes of the project. Our project has looked at

intermediate outcomes: institutionalization and sustainability. They are intermediate in the sense that they are means to an end—more and better educated STEM technicians—rather than the end itself. While our analysis can tell us a great deal about the program process and the potential mechanisms through which it might work, in the end we will need more evidence of the eventual program effects. This type of information will allow us to gain more understanding about institutionalization and sustainability. For example, we may find that different types of institutionalization lead to different types or levels of outcomes. Studying outcomes in a program that is as diverse and decentralized as the ATE is extremely complex. The characteristics of the program make a straightforward experimental design difficult, especially at this early stage of the program's development. Nevertheless, considerable progress can be made through a better and more comprehensive understanding of the changes that the ATE initiative has brought about in the country's system of STEM education. Most projects and centers have their own evaluators, and one step might be to work towards more standardization of their efforts and to promote more communication among them.

The National Science Foundation's Advanced Technological Education program is an exciting experiment in improving a crucial component of the nation's education system that has made significant progress during the decade in which it has existed. It has brought together community colleges, universities, high schools, businesses, commercial publishers, and other groups in a unique initiative to improve the education of STEM technicians at a time of rapid and profound change in the technologies with which those technicians must work. So far it has a strong record of accomplishment, particularly in the influence that it has had on curriculum and professional development. Our report

suggests that the ATE program now has a solid base on which to build a stronger focus on broader organizational and cultural change. The NSF, in its management of this initiative, is already moving in that direction. We suggest that these developments can be further strengthened by a more explicit understanding of the barriers that the program is trying to overcome and by carefully tracking the experience with, and effects of, overcoming those barriers.

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